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DEVOTED TO

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Prof. Persifor Frazer, D.Sc., Prof. Edwin J. Houston, Mr. Theo. D. Rand,
Prof. Coleman Sellers, Prof. H.W. Spangler, Mr. S. Lloyd Wiegand,
Committee on Publications, with the Assistance of
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THE UNITED STATES LIFE-SAVING SERVICE.*

BY HORACE L. PIPER,
Assistant General Superintendent of the Service.

The preservation of life from shipwreck was not among the objects which early enlisted the interest of men. Even as commerce extended its scope the goods, not the sailors, were the objects of its solicitude. When the owner's right to his property was made to depend upon the fact that somebody should get ashore alive it became a matter of care to the plunderers on the coast that nobody should reach the shore alive, or if anybody did that he should straightway be put to death for his folly. To be sure, the coveted goods would not therefore lawfully belong to the wreckers, but "dead men tell no tales."

Although death in hideous form had long prior been denounced in England upon persons who, "more barbarous, cruel, and inhuman than mad dogs, murdered shipwrecked folk," the eighteenth century was well in its twilight before any organized effort, and that private, was made for the succor of such unhappy creatures. Our Declaration of Independence had been proclaimed and made good before such a thing as a life-boat had been conceived in England, where the first one was invented, and George Washington had been two years in our presidential chair when the first serious steps were taken in "the mother country" for the rescue of the shipwrecked.

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* A lecture delivered before the Franklin Institute.

The good people of the United States were no laggards in this great work. The year 1786 witnessed the organization in Massachusetts of the Humane Society of that commonwealth, which three years later formally dedicated its energies to the rescue and relief of castaways on that coast. So, it happily appears that a life-saving service of some sort, limited and imperfect it is true, began its career with the infant steps of the Republic. The Massachusetts society was the first organization of the kind in this country of which I have knowledge, and if it may not be called the parent of all others, it was at least the pioneer. Though already a centenarian, let us hope that it is still in the flower of youth.

The life-saving service of the United States had its inception in the year 1848, when Congress first made an appropriation for such an agency of the general government. It may be worth while to note the fact that this was also the year in which attention was re-awakened to the same subject in England, where it had languished to such an extent that a recognized authority declares the whole system to have been "in such a low state that in the entire kingdom there were perhaps not a dozen really efficient life-boats." But our appropriation of 1848 was only a beggarly pittance of $10,000, to be expended solely upon the coast of New Jersey. A few boat-houses were cheaply erected and equipped with this sum, but although small appropriations were subsequently made for additional houses and equipments at other points, no crews were employed until 1869, and then only at alternate stations.

While it might not be true to say that the service from 1848 to 1871 was discreditable, it certainly was not brilliant. Its new and glorious career began on the 20th of April, 1871, when Congress made an appropriation of $200,000 for life-saving purposes, to be expended by the Secretary of the Treasury through the medium of the Revenue Cutter Service, with which life-saving operations were then connected. The chief of the Revenue Cutter Service, at that time, was a young man who had only a few weeks before taken charge of the office, and who had himself suggested the appropriation mentioned, and devised a scheme for its judicious expenditure. The marvellous results achieved with this comparatively small sum, the record showing that on the coast of Long Island and New Jersey, to which the appropriation was limited, every life imperilled by shipwreck during the following season was saved, induced further favorable action by Congress, gradually enlarging the service, and finally by the act of June 18, 1878, organizing it into a separate bureau.

Mr. Sumner I. Kimball, the chief of the Revenue Cutter Service, to whom I have just referred, was nominated by the President, and without the usual reference to a committee, unanimously confirmed by the Senate to be General Superintendent of the new Life-saving Service. This remarkable tribute of confidence was not accidental—it was earned. During his administration of the Revenue Cutter Service, Mr. Kimball had raised its status from one of waning importance and efficiency to a very creditable footing, and at the same time had elevated the Life-saving Service to such a plane that it began to command general interest and confidence. His assumption of the new office was marked with vigor and enterprise.

DISTRICTS AND SUPERINTENDENTS.

Without undertaking to enumerate in full detail the various steps in organizing and perfecting the economy and morale of the service, let me proceed at once to submit, first, an outline of the organization as it now exists, and then as complete a *résumé* as possible within our limits of its operations.

The coasts of the Atlantic, Gulf of Mexico, Great Lakes and the Pacific—Alaska not included—comprising more than 10,000 miles, are divided into twelve life-saving districts, designated by number, beginning with Maine on the Atlantic, and terminating with Washington on the Pacific. The first district includes the coast of Maine and New Hampshire; the second, Massachusetts; the third, Rhode Island and Long Island; the fourth, New Jersey; the fifth, Delaware, Maryland and Virginia to Cape Charles; the sixth, Virginia and North Carolina from Cape Henry to Cape Fear; the seventh, South Carolina, Georgia and Eastern Florida; the eighth, the Gulf of Mexico; the ninth, Lakes Ontario and Erie; the tenth, Lakes Huron and Superior; the eleventh, Lake Michigan; and the twelfth, the Pacific Coast.

Each district is in charge of a superintendent, chosen for his knowledge of the subject, business capacity, and executive ability. He must be a resident of his district, of good repute, not less than twenty-five nor more than fifty-five years old when appointed, is required to understand the use of life-boats and life-saving appliances, and to be familiar with the lines and dangers of the coast under his guardianship. He is the disbursing officer of the district, under a bond ranging from $10,000 to $50,000 in amount, must visit every station once in three months, oftener when necessary, examine and test the crews as to drill and discipline, and has general supervision of the property, surfmen and operations.

The single-hearted devotion of many of these men to their noble work is a matter of well-deserved admiration. To them their vocation is much more than the mere holding of office with pecuniary reward. Nothing draws one so close to another as a kindred woe. Some of these men have themselves felt the clutch of the icy waters about them, and have been saved by only a little less than a miracle. In them the hoarse wail of the storm awakens the deepest emotions and the best impulses of human nature. Several have immortalized their names by acts of extraordinary heroism well worthy of recital here, but omitted for obvious reasons. Some have made important inventions and improvements in life-saving appliances, and all are men of excellent reputation in their profession.

STATIONS AND THEIR LOCATIONS.

The districts are subdivided into stations, known by the names of their localities, and situated with regard to the special dangers of the coast. They are of two kinds: complete life-saving stations, and houses of refuge. The former have a building constructed of wood without much reference to architectural effect, but designed to withstand the tempest, and afford comfortable quarters for the surfmen and convenient rooms for the apparatus. On the first floor there are a boat-room, kitchen, keeper's office and sitting-room for the crew; on the second floor, the sleeping apartments. A lookout tower for the day-watch is placed upon the roof or near by, and there is a flag-staff for signalling, the service co-operating in this matter with the maritime associations of the country. A wreck-pole is also generally set up in the vicinity for the purpose of practice with the breeches-buoy apparatus. The equipments usually comprise two boats with outfits, a life-car, two sets of the breeches-buoy, a Lyle life-gun, cork jackets, heaving-sticks, night-signals, rockets, signal-flags, barometer, thermometer, necessary furniture, etc. Crews, generally consisting of six men and a keeper, are maintained during the active season—defined hereafter—the keeper being required to reside at the station the year round, unless granted an occasional short leave of absence during the inactive season, when a substitute must be furnished.

A house of refuge is provided with a frame house of sufficient capacity to accommodate as many persons as are likely to be cast on the adjacent shore, and furnished with the means of supplying their immediate wants. A small boat is supplied for the use of the keeper, but no crew is maintained. The keeper and his family reside in the house, and the beach is patrolled by them at such time as wrecks are likely to occur.

The whole number of stations of both kinds at the present time is 240, several of them not yet fully completed and manned.

By far the greater part of our ocean commerce is on the Atlantic, and on that dangerous coast are located a majority of the stations. On the coast of Maine and New Hampshire there are ten; these shores, though rugged and stormy, having excellent and numerous harbors of refuge. The Humane Society of Massachusetts renders good service from the New Hampshire line to Race Point on Cape Cod, and therefore the United States provide protection for only a half-dozen especially dangerous points within those limits. In Mr. Kimball's address before the recent International Marine Conference, Cape Cod is aptly described as a narrow strip of sand, stretching directly out into the ocean some forty miles, then turning abruptly northward for an equal distance, like a threatening arm, its bars and beaches being the burial-ground of unnumbered craft. Here ten stations keep "watch and ward," at nearly equal distances apart, and well arranged to coöperate with one another. From the extremity of the Cape to Montauk Point there are nine.

White-winged messengers of commerce swarm along the coasts of Long Island and New Jersey as a multitude throngs the principal thoroughfare of a metropolis, and these shores are abundant with perils. On Long Island there are thirty-nine and on the New Jersey coast forty stations. From Cape Henlopen to Cape Charles seventeen treacherous points are guarded; from Cape Henry to Cape Hatteras—the sailors' traditional horror—twenty-three. On the coast of Florida, wrecks are usually cast well upon the land, the shipwrecked generally reaching the shore in safety, but sorely in need of temporary shelter and sustenance. Here are located the houses of refuge, ten in number besides one fully-equipped station at Jupiter Inlet, a point of considerable danger, about two-thirds of the way down the coast. The Gulf of Mexico has points of sufficient importance to call for eight complete stations.

Passing up to the Great Lakes we find five immense bodies of water with few natural harbors, and freighted with commerce of amazing proportions. Here the mariner finds the dreaded lee-shore always under his forefoot. The extraordinary dangers of these land-locked waters furnish ample work for forty-nine crews. On the Pacific Coast, strandings are not frequent, the prevailing winds blowing along rather than upon the shore. To the present time twelve stations have been located there.

KEEPERS.

Every station is in charge of an officer who is really the captain of the crew, but is technically known as the keeper, that designation having been made in the early days when only one man was employed merely to keep the apparatus in order for the use of volunteers on occasions of wreck. The keeper is the person who directs the actual operations of life-saving. He decides upon all the movements, commands and steers the boat, and exercises absolute authority over the crew. There are difficult and fearfully important questions to be decided, and the decision must be made then and there, under the pressure of excitement, with human life trembling in the balance. Obviously this officer should be a man of skill in the surf, of sound discretion, of dauntless courage. He must be able-bodied, level-headed, and like Nelson, unacquainted with fear.

As in the case of superintendents, the selection of keepers is a matter of great moment to the service. They are generally nominated by the district superintendents, with a written statement of reasons upon which the nominations are based. If approved by the general superintendent, appointment follows. Keepers must not be under twenty-one nor over forty-five years of age upon entering the service, and are required, aside from the requisite qualifications of surfmen, to possess sufficient education to keep the records of the station, and conduct ordinary correspondence. Under this system an excellent body of men has been secured. Their record for courageous conduct in the face of extreme danger is without stain, but there have been some instances where a fatal error of judgment has required a keeper's removal. I recollect such a case (the error resulting in loss of life) where the keeper distinguished himself by the display of remarkable courage on the very occasion of his failure, risking his life with reckless daring, and even suffering physical injury. The general superintendent was criticised for this removal as an act of unnecessary harshness, but his conclusive reply was that when human life is at stake, whatever may be second among the qualifications of a keeper, unquestionable sound judgment must be first.

The keepers of complete stations are generally paid $700 per annum. The Secretary of the Treasury may, under the law, allow a maximum of $800, but this sum is awarded only in cases where keepers have won special merit by the exhibition of superior courage and capacity. Keepers of houses of refuge receive $600 each per annum.

CREWS.

The crews are technically known as surfmen. Nobody need tell you what stuff they should be made of—the hazardous nature of their vocation tells that. Mere sailors will not do. Between the average sailor and a genuine surfman there is a wide difference; the former frequently, I might say generally, knowing little of surf-life. These crews must be surfmen, they must be the best, with muscles of steel and hearts of oak. They are selected by the keeper from the best men obtainable in the neighborhood, and must not be over forty-five years of age when originally enlisted. They are admitted only after rigid examination as to their physical and professional qualifications. They may not be discharged without good cause, and (with only two exceptions) not without special authority from the general superintendent. The exceptions noted are neglect of patrol duty and disobedience at a wreck, for either of which a keeper may dismiss a man on the spot. Happily these offences are of rare occurrence. Almost always the surfmen have displayed royal qualities crowned with dauntless courage. Their pay is $50 per month, during the active season only, and $3 for each occasion of service during the inactive season. From the meagre sums paid to keepers and surfmen, they must supply their own food and clothing.

That the rates of compensation are less than just is hardly an open question. At all events, as long as they prevail, the service may be considered safe from the assaults of unworthy seekers of soft places with fat salaries.

DISCIPLINE.

Here is a large corps of men, numerously subdivided and widely scattered, whose efficiency depends upon discipline; how is that secured? In the first place, the discipline of the crew devolves upon the keeper. He is required to keep a daily log or journal, in which must be noted all official transactions, including drill with the boat and practice with the beach apparatus. A transcript of the journal must be forwarded each week to the general superintendent at Washington, through the district superintendent. The keeper may generally be relied upon to report any serious infractions of the regulations, because, besides being required to do so, the maintenance of his own authority demands it.

But who is to maintain the watchful eye upon the keeper? Primarily he is under the charge of the district superintendent, who must make an inspection of all station affairs upon his quarterly visits, and render a report in writing to headquarters at Washington. There is also in each district, an assistant inspector—an officer of the Revenue Cutter Service, detailed for the duty—who is required to make a tour of the stations once every month during the active season; oftener if occasion should require. This officer drills the crew, examines them in their various duties, and is especially charged with matters looking to good order and discipline. He must also make a written report to headquarters at Washington. Then there is one general inspector of the service. Among a variety of other duties, he must make periodical inspection of all the districts, and file a report in detail at headquarters in Washington. Thus, it will be perceived, reports are constantly flowing from the branches to the centre of the service.

With a view to entire equity as far as possible, the general superintendent has not discouraged those whom I may call the the privates in the ranks, from holding communication with himself, when they may feel that they should be heard directly without intervention. And yet all this would not make sure that condition of proper restraint and reasonable freedom essential to healthy *esprit de corps* if there were not at the head, an ungloved hand upon the helm. The dignity and authority of the officers must be maintained, the rights and self-respect of the men preserved. No failure of duty is excused except upon strong reason, after searching investigation. The grievance of the humblest surfman is inquired into, and rectified if well grounded, with all the care and impartiality which attend the treatment of a complaint preferred by the highest officer. The result is that discipline is good, and there is coëxistent with it, that feeling of restfulness and contentment among the men which is indispensable to a healthful and successful service.

OPERATIONS—BOATS.

On the Atlantic Coast the "active season" opens on the 1st of September and closes on the 30th of April; on the lakes, it opens and closes with the opening and closing of navigation; on the Pacific the stations are open and manned the entire year, disasters occurring there more frequently from local causes than from mere stress of weather, and being about as likely to happen at one season as another.

On the Atlantic, the 1st of September witnesses the muster of the crews. The men are told off by numbers, the presumably best surfman ranking as number one, next to the keeper, the others in regular numerical order according to known or supposed qualifications. The rules are read, and the house is set in order. Usually the members of the crew take turns in cooking, though they sometimes prefer to employ a cook. The domiciliary preparations having been completed, regular drill is begun, each day being set apart for a special purpose. The surf-boat or the life-boat is taken to the water, launched, and worked in the surf. Probably few who have ever gone out or come in through the breakers in a well-handled boat, have any adequate idea of the danger. This operation involves the most difficult boat management known to the sea, even on an ordinarily calm day. When the ocean is disturbed by the storm, the waves are lifted in huge volumes many feet into the air as if by some great magnet, which suddenly loses its power, and they fall with a deafening roar, chasing each other in fury across the beach often to the high land. The boat must never be caught on the crest of one of these foaming billows, but must lag behind, or run before them. These are tricks to be played with a treacherous foe, and woe to him who makes a mistake. In such case the boat is either broached to and capsized, or lifted on end and toppled over, when the hapless crew must swim for their lives.

Nothing steadies a boatman's nerve so much as confidence in his craft. He must feel that she is agile and seaworthy, and will not play him false. In pursuit of these qualities the service has expended indefatigable industry. On the more important parts of our coasts, the English life-boat would be useless. It is a grand boat, and there clusters about it a glory of successful effort, which has made its very name honored and beloved, but its great weight restricts its use with us to exceptional localities. It weighs from two to four tons, is furnished with a heavy iron keel to secure the self-righting quality, and draws a good deal of water. Imagine seven or eight men on any of our flat beaches attempting to push one of these to deep water. Twenty men would exhaust their power and fail in the undertaking. Where these noble boats may be plunged at once into water of sufficient depth they are admirable, but for general purposes we have excellent models much less than half the weight of the lightest English life-boat, and possessing its best qualities. The Beebe-McLellan surf-boats are self-bailers, and as now equipped, readily righted if capsized. They are of light draft, easily launched and handled, and our crews have accomplished with them prodigies of surfmanship.

The Dobbins life-boat, although heavier, is still comparatively light, and well adapted to the demands of many of our stations, where it has proved its efficiency. The same may be said of the Richardson life-boat. All three of these boats have been invented or adapted by the skill and intelligence of officers of the service. There are also in use at appropriate places a number of boats of the English model.

Surprise is sometimes manifested by persons unacquainted with the use of life- and surf-boats, that capsizes take place. It should be understood that no boat has yet been invented which may not be upset. If such were not the case, there would be no need of the self-righting quality, and a self-bailer furnished with air cases so that she could not sink, would make life-boat service little more than a matter of exhilarating pastime. But while a capsize is liable to occur at any moment, our service has been reasonably free from serious casualties in this way. During the existence of the present system there have been some sixteen cases including various types of boats, involving a loss of twenty-eight surfmen and fourteen shipwrecked people. During the same period, the English life-boat, which is selected for comparison, because heretofore supposed to possess every attainable best quality, has capsized twenty-one times, with a loss of sixty-eight boatmen and seven shipwrecked persons. When the number of times our boats have been in service and the number of persons involved are considered, the percentage of loss is perhaps as small as may ever be expected—certainly so until some now inconceivable invention has rendered a capsize next to, if not absolutely, impossible.

BREECHES-BUOY—LYLE-GUN—LIFE-CAR.

Boat drill alternates with practice in working the breeches-buoy apparatus. This device is like a pair of trunks or knee breeches made of canvas with a circular life-buoy for a waist belt, and is hung by four small ropes to a pulley running on a hawser. First, a small line about a quarter of an inch in diameter and very strong is thrown over the ship with the gun. This line is hauled on board by the sailors, having attached to its shore end an endless larger line called the whip, run through a pulley, to which is attached a tally-board with directions for its adjustment on board printed in English and French. When the whip-line block reaches the vessel it is made fast by the sailors, well up on the mast if possible. The rest of the work is done by the life-savers. Hauling on one part of the whip, they send out a three-inch hawser, also bearing a tally-board with instructions that it be made fast just above the whip-line. The shore end of the hawser is anchored in the sand, and raised from the earth on a tripod or crotch. Then the breeches-buoy is swung to the hawser, fastened to the whip, and all is ready. By pulling on one part of the whip the buoy is sent out, and by reversing the action drawn back, each return generally bringing to the shore in safety one or two people. By this simple contrivance thousands of lives have been saved. Practice with this apparatus is conducted on shore with the wreck-pole, already referred to, serving as the mast of a disabled vessel. The life-gun is the invention of Capt. David A. Lyle, a distinguished officer of the Ordnance Corps of the United States Army, whose name it bears. It is composed of bronze, and with its line-carrying projectile, weighs a little over 200 pounds. It has a range, under the most favorable conditions, of nearly 700 yards, and has so far nobly met the requirements of the service.

The safety of the breeches-buoy as a means of rescue is well established by the fact that there is but a single instance on our records where a person once embarked in it has been lost.

The life-car now in use in our service embraces the essential features of the "Francis Metallic Life-Car," made famous some forty years ago by the rescue of a large number of people from the wreck of the *Ayrshire*, on the coast of New Jersey. The car of the life-saving service is constructed of metal in the shape of a boat, sharp at both ends and housed in. Access is had by way of a small hatch, which may be securely fastened either on the outside or inside, and the car may be drawn to and fro, either suspended on a hawser, or through the water. It is of sufficient capacity to accommodate several persons.

LOOKOUT—PATROL—TELEPHONE.

From sunrise to sunset the lookouts by turns keep their perch in the lookout tower, and when night approaches the patrols prepare for the lonely tramp along the shore. At any hour from night-fall to day-break, during the eight stormy months of the year, were you to find yourself on a beach protected by the life-saving service, you would be sure of meeting one friendly traveller to give you greeting.

The importance of this system of patrol at night—and by day in thick weather—cannot be overestimated. It makes sure that a wreck shall not come tumbling in, and be left undiscovered and helpless for hours when moments are precious, and delay is almost certain to result in unnecessary if not wholesale loss of life. By the patrol system a wreck is almost always discovered within an hour, generally in a few minutes.

The labor and hardship patrol duty imposes upon the surfmen are not likely to be fully appreciated until one is informed of the difficulties and dangers attending it. On some of our beaches the patrol is at all times compelled to wade for considerable portions of his beat through small streams and inlets, and when the tide is unusually high or the rivulets are swollen to formidable proportions, his duty is never without peril to his life. It not unfrequently happens that the way is lost, or the stress of circumstances compels a deviation from the usual course, when unseen and unknown dangers are encountered, such as bluffs and gullies, occasioning frequent injury by falling, etc.

The six members of the crew are divided into three reliefs of two men each, the first relief doing duty from sunset to eight o'clock—the men going in opposite directions—the second from eight to midnight, the third from midnight to 4 A.M., and the first again from 4 A.M. to sunrise, the order being so changed from day to day that the double duty of the first relief, as above indicated, shall not fall to the same individuals.

The patrolman is equipped with a lantern, a night signal or two, and a check. The lantern lights his way; the signal—something like a Roman-candle burning a brilliant red light—is carried to warn off vessels standing into danger. During the last year 227 vessels were warned away and saved with many valuable lives by this simple beacon light. The check the patrolman carries to exchange with his fellow on the adjacent beat, each taking back as a voucher of his fidelity, the one received from the other. Sometimes, alas, the check is never exchanged. Darkness and tempest and pitfall with exhausted human energy have conquered the brave heart, and its pulsations have expired on the stormy pathway of duty. It is a perilous task to traverse those desolate shores for miles in weather which would deter us from the streets of Philadelphia, and I can imagine no sadder scene than that which has been witnessed more than once in our service, of a search party tenderly bearing back to the stricken station the body of a comrade fallen by the wayside, every man impressed with the knowledge that come what may another must complete the broken journey.

Pertinent to lookout and patrol duty, and very closely related to it, may be mentioned the system of telephonic connection now widely used in the service. Where the coasts are most dangerous the stations are most numerous, and therefore nearest together, enabling them if informed of a disaster to coöperate in the work of rescue. The telephone furnishes a ready means of communication by day or night, and without the necessity of special operators to use it. The admirable results obtained in this way may be illustrated by the fact that as many as three crews have thus been brought together for combined service within less than two hours from the discovery of a doomed vessel.

While this feature is perhaps the most important, it by no means comprehends the entire benefits of the telephone. Nothing exerts a stronger influence upon individuals and communities than contact and association with others. Ambition and competition are thus aroused. Precisely this effect has been produced upon the morale of the service by the introduction of the telephone. A few men set apart in an isolated position, without outside associations, generally develop a tendency to sluggishness and demoralization, but when the telephone informs a crew that their neighbors are up and doing, out in a heavy surf, or at work on the beach, setting up the apparatus and landing a man in less than eight minutes—as is often done at drill—they are apt to conclude that they are just as capable as their enterprising comrades, and are generally not long in going to work to prove it. In this and similar obvious ways the telephone has proved an invaluable auxiliary to the efficiency of the service. To the present time, about one-half of the whole number of stations have been supplied with telephonic service. Extension is being made where feasible and desirable, as rapidly as circumstances admit.

WRECKS.

When a wreck is discovered at night, a signal is burned to inform the disabled vessel that succor is at hand, and the patrolman hastens to the station to give the alarm. Then there is hurrying to and fro. Every man is on duty. The beach apparatus is at all times stowed in the hand-cart in an orderly manner, having reference to the sequence of the use of the various parts. This apparatus consists of the gun for throwing the shot-line, the whip-line, hawser, sand-anchor, breeches-buoy, shovels, lanterns and implements necessary to set up the gear. The surf- or life-boat, with its equipments, is always mounted on the wagon, and everything is ready, as in the engine house of a city fire department, to proceed without delay to the scene of operations.

Although the stations are located at points where wrecks are most likely to occur, the actual disaster is often several miles away. If possible, horses are used to draw the boat, while the men harness themselves to the hand-cart, each man always taking the same relative position. The cart with its load weighs upwards of 1,500 pounds, and the journey is often a toilsome one, the sea frequently running across the entire beach to the sand dunes, commonly called the sea-wall, the men being then compelled to plod their way over a yielding surface, or seek a more solid road further to the rear. Sometimes the route leads through the forest, where a passage must be hewn with axes, so that the crew reaches the beach abreast the wreck in a condition well nigh approaching exhaustion, while the battle with the sea is still to be fought.

Then comes the question of method—shall the boat be used or the life-line? Meantime the roaring, tumbling, eager waters are doing their deadly work. Whatever is to be done must be done quickly. Here is a situation which makes a blunder almost as bad as a crime. If practicable, and especially if the stranded vessel is likely to break up at once, the boat is tried. This is required to be done because it is the readiest method, and if successful results in saving many lives at once; but to launch a boat in the face of an angry surf is frequently beyond the compass of the utmost skill and resolution. However, no keeper is excusable for failing to make an effort unless it would be obviously and beyond dispute foolhardy, or is clearly unnecessary. In such cases the breeches-buoy or the life-car is employed. The success of these methods depends upon the possibility of getting a line to the ship, which must be done with the gun, unless, as rarely happens, one is sent ashore by a float from the wreck.

Usually the gun is capable of reaching the vessel, and when communication is once established with the shot-line the first and great problem in the use of the breeches-buoy or the car practically disappears. The lines and hawsers are of the finest quality, and seldom, almost never, break. These three methods, the boat, the breeches-buoy and the life-car comprise all the means of life-saving known and used in the world. When they have failed, hope may well give way to despair.

RESULTS.

Omitting anything like an exhaustive statement, let me submit a few figures epitomizing the great results accomplished by the present system. During the destructive tempest of September, 1889, three crews in the vicinity of Cape Henlopen rescued 194 persons from twenty-two stranded vessels, thirty-nine being landed by boats, 135 by the breeches-buoy, and twenty by the life-car, not a soul being lost. On the 3d of February, 1880, in a night of intense darkness, wild with sleet and snow, the entire crews of four vessels were rescued upon the coast of New Jersey without the most trivial mishap. The appliances were set up and worked by the dim rays of ice-covered lanterns, under the most discouraging circumstances. It would be almost impossible to imagine better evidence than this of the usefulness of the daily drill to which I have already referred. During that year (1880), only nine persons were lost out of 1,980 imperilled. The smallest number lost in any other year was seventeen out of 3,950 imperilled. In the memorable March blizzard of that year (1888), fourteen sail vessels and two steamers were assisted near the Lewes, Del., breakwater, only two persons being lost. Four crews, thirty-two men, on the Delaware coast, served in the two years, 1888 and 1889, at sixty-five wrecks, rescuing 499 persons (an average of fifteen lives saved for each individual surfman).

Although the scope of a station's operations is usually limited to a few miles, much longer distances are sometimes made. Probably the most remarkable instance ever recorded occurred on the 18th of November, 1886. On the morning of that day, two ghostly figures, proving to be two vessels in distress, were discovered off the town of Marquette, on Lake Michigan. There was no life-saving station there, and the people of the vicinity devoted the entire day to every sort of effort to reach the forlorn mariners. Boats and steam tugs were tried, a mortar and life-line were invoked. All failed. With the departure of daylight a pall of horror and dismay enveloped the town. The nearest life-saving station was at Ship Canal on Lake Superior, 110 miles away. Faintly hoping, almost despairing, a telegram was sent stating the appalling facts. A special train was at once ordered at the nearest railway station to Ship Canal, and the crew and apparatus were hastily embarked in the midst of one of the heaviest snow storms of the year. Before midnight the life-savers reached the scene of disaster, and after eight hours of indomitable effort, safely landed the two entire crews, twenty-four persons. During that year out of 6,601 lives imperilled, only fifty-eight were lost.

From 1850 to 1870, there were lost on the Long Island and New Jersey coasts alone, 512 lives—an average of twenty-five per annum—while under the present system from 1871 to 1889, with a largely augmented commerce and corresponding increase of disasters, there were lost 119, an average of less than seven per annum, a reduction of eighty per cent. It may be stated also that the figures for the former period (no official record having been kept) are undoubtedly far short of the true aggregate, while, for the latter period, all disasters are included. Taking the scope of the entire service into account, the loss of life under the present system has been only a small fraction over one in 100.

To summarize the whole matter in a single statement, the entire loss on all the coasts of the United States under the present system since 1871 has been only thirty-eight in excess of the loss on the Long Island and New Jersey coasts alone during the preceding twenty years. Twenty-eight of these were wreckers, who rashly cast off the lines of the Life-saving Service already on board, and declined assistance until too late to be of any avail.

We have attended at 5,452 disasters, involving 46,383 lives, of which only 550 have been lost, including the twenty-eight unfortunate wreckers just mentioned, who were unquestionably the victims of their own folly. In addition to this grand total of lives preserved, we have saved and assisted to save property to the value of $89,337,179.

A NON-PARTISAN SERVICE.

It is assumed that the status and achievements of the Life-saving Service, even as imperfectly set forth in these remarks, must command general commendation, and I should be loth to close without naming the one factor, which perhaps more than any other in my opinion, has contributed to the splendid result. That is its non-partisanship.

In his annual report for 1880, the present general superintendent, urging the necessity of a statute to place the service on a non-political basis, recognized and sanctioned by the law of the land, made use of the following language:

"The last section of the proposed bill embodies the important provision that *the appointment and employment of all officers and crews of the Life-saving Service shall be made solely with reference to their fitness and without reference to their political or party affiliations.*

"Much has been said in previous reports of the service, upon the necessity of selecting its agents strictly upon grounds of professional qualification, entirely ignoring all considerations of party or creed, and everything, in fact, but the plain business in hand. The sober sense of every thinking person, will, it is believed, approve this line of conduct. The purpose for which the establishment is organized is simply to save life from wrecks, and, secondarily, property; and to most effectively carry out this purpose the service must not be conducted in the interest of any platform or doctrine. The Life-saving Service is eminently one of experts, and its agents must be the ablest trained professionals that can be secured.

"When the wrecked vessel is swept fore and aft by the winter seas, and haggard sailors and sobbing women and children are clinging to shroud and bulwark, the man who can best take out the life-boat through the breakers to their rescue, is the man of all men for this service, though he be a pagan. The gunner that can cast at the first fire the shot-line over the breaking deck when the stormy night is blackest, and there is nothing to guide his aim but the spot of light made by the ship's lantern in the rigging amidst the rending surf and overleaping spray, be will proclaimed, by the sufferers his wreck-craft brings to shore, the man this service demands, though every caucus on the coast denounce his politics. If a patient be in mortal danger, and to save his life a capital operation is to be performed, we send for the surgeon. We raise no question of creed or party—we want only the surgeon, and we want the best. When the wreck is beating into ruin on the lee shore, the case is equally one of life and death, and equally, to the exclusion of every other consideration, is the highest professional ability required.

"Limiting the consideration simply to politics, it may be said that the required expert might be found in the ranks of the dominant party, and therefore chosen in the interests of that party. But the moment the principle of a political qualification is admitted, the selection, even from the party itself, is liable to be fatally influenced, because another object is introduced, namely, to reward some past political service, or to secure such service in the future, and the choice, as in the case of most political appointments, would then be made upon the recommendation of men of political prominence and aspirations in the locality of the position to be filled, in whom personal interest, the desire for party triumph, or the heat of party contest might bias the judgment or create the temptation to ignore or lower the professional standard, to palter with the facts of character and conduct, or to blink defect and incapacity, thus leading to the imposition upon the establishment of officers and surfmen in respect to their ability to control votes and carry elections, rather than to save human lives at shipwrecks. Such a rule, once put in operation, however good in intention, would end by supplanting superior agents with agents less good, or good for nothing.

"The effort to conduct the service without reference to such considerations has not been accomplished, it is needless to say, without serious difficulty. The success is only due to constant firmness on the part of the officers in its immediate charge, invariably supported, it is gratefully acknowledged, by superior official authority. But other men must succeed them, who, perhaps, unwarned by an official experience, may have less resolution, or entertain different convictions, or who may simply serve the policy of future administrations possessed with views of the entire compatibility of such a service with party politics. The time for such a change in the fortunes of the Life-saving Service may come, and in the stations trained surfmen may one by one give way to mere party hacks, perhaps even to the point of entire substitution. But if it does come—and this conviction it is desired to put on record—from that time the usefulness of the service will be on the wane. Its efficiency is coëxistent with its continuance in the hands of the best surfmen, chosen only for their professional mastery of the methods it employs.

"The section of the bill referred to would erect the only solid barrier which can protect the service from the dreaded encroachment.

"When by statute there can be no question of the singleness of purpose of the service, the answer to those who would use it for other ends is made before they arrive. This provision of the bill is therefore earnestly recommended."

On the 4th of May, 1882, an Act of Congress embodying the provision urged in the above quotation, was approved by the President of the United States. It is the law; it has been faithfully observed, and as long as it continues to be the service must command public confidence and will succeed.

When a wreck is pounding on the rocks the business in hand is to save all on board; no inquiry is raised as to their nationality, color or politics. Neither does the service ask nor care whether the life savers are democrats or republicans, mugwumps or prohibitionists, orthodox or heretic, so that they are upright, brave and able surfmen. It is a nonpartisan service; it is a humane service—sweet as charity, broad as humanity. Standing on this noble eminence, above the strife of party and creed, "like some tall cliff above the storm," standing, as it confessedly does, at the head of all similar institutions in the world, every American may love it, aid and defend it.

THE SUBNORMAL IN GRAPHICAL DYNAMICS.

By Irving P. Church, Ithaca, N. Y.

Probably a large proportion, if not a majority, of students of applied mathematics are led to the appreciation of a law, principle, or relation, more easily by a graphic, than by an analytical, illustration or proof. Accordingly we find that most text-books of mechanics, in the presentation of the subject of the rectilinear motion of a "material point" (or "physical point"), among other modes of treatment employ graphical methods of showing the relations between any two or three of the four variables involved (viz: *distance*, *time*, *velocity* and *acceleration*), the values of two variables being plotted as abscissa and ordinate, to give points in a curve.

For instance, taking as an abscissa the distance (s) of the body (material point) from a fixed origin in its path, and as an ordinate the time (t) which has elapsed since the body passed that origin, we obtain a curve at the various points of which the co-tangents of the angles between the tangent lines and the axis of abscissas are proportional to the velocities (v) of the body in passing the corresponding points of its path; since

$$\frac{ds}{dt} = v. \tag{1}$$

Similarly, with the velocity (v) as ordinate, and the time (t) as abscissa, the tangent of the "tangential angle" varies as the acceleration (p) of the motion; since

$$\frac{dv}{dt} = p. \tag{2}$$

By eliminating dt from eqs. (1) and (2), we obtain the familiar relation

$$v\,dv = p\,ds. \tag{3}$$

While the conception of the velocity of a moving point at a certain instant is a comparatively simple one to the student, that of its acceleration at the same instant is rather elusive and needs building up by a variety of modes of illustration in the case of a beginner in mechanics. Now the representation of the acceleration by the tangent of an angle is neither convenient nor impressive, in graphic illustration. A *length*, however, that can easily be constructed and scaled off, whose variation during the motion, even without actual construction and scaling, can be roughly followed by the eye, and whose *position* is identical with that of the resultant force, would seem a much more effective representative for the acceleration; since the acceleration is proportional to the resultant of all the forces acting on the body at any instant and a force is usually represented by a definite length having both magnitude and *position*.

It is the object of this brief article to present and illustrate a simple method of the writer's for the graphic construction of the acceleration at any point of the path of a material point, whose motion is rectilinear, when the velocity (v) is given as a function of the distance (s) of the body from an origin in its path; *i. e.*, when we have given a curve with s for abscissa and v as ordinate, whether plotted from an equation or from the results of experiment.

Construction.—In *Fig. 1* let O be the origin and OS the actual path of the body. Suppose a curve $A\ B\ C$ has been constructed whose (horizontal) ordinates (x) are proportional to the velocities (v) for the corresponding positions of the body. Thus denoting by n the scale-number (arbitrary constant) adopted in laying of these horizontal ordinates (*e. g.*, if six velocity units, or six feet per second, are represented by one foot of distance, $n = 6$) we have $v = nx$, and

$$x = \frac{v}{n};$$

and $dv = n\,dx$. We here suppose the body to have some initial velocity $c = nx_0$ on leaving (or passing) the origin O.

m being any point in the path of the body, draw the corresponding ordinate x to determine the point q in this "velocity-distance curve," as it may be called. A normal drawn to the curve at q will intersect the axis OS (*i. e.*, the path of the body) in some point N. Then the acceleration (p) of the motion at m is $p = n^2 \times$ the distance $\overline{mN}$; *i. e.*, $p = n^2 \times$ the length of the subnormal, $= n^2u$. That is to say,

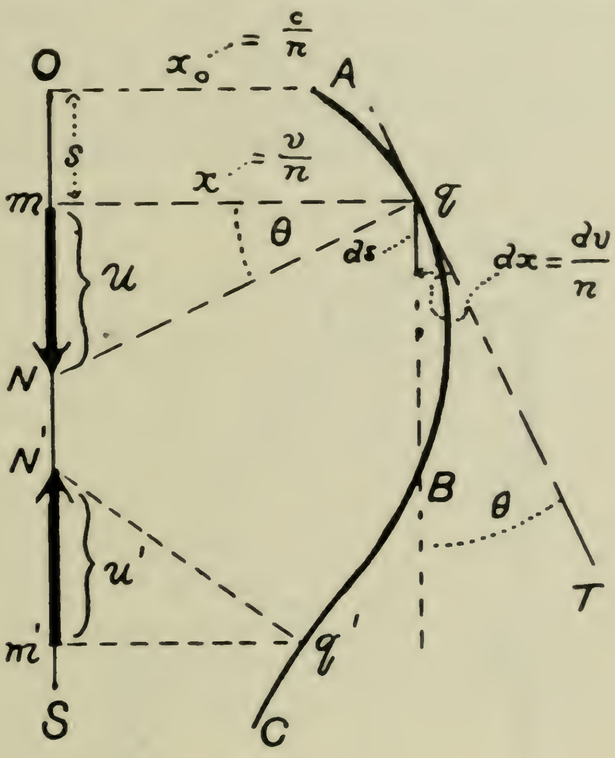

FIG. 1.

n being constant, *the acceleration is proportional to the subnormal of the "velocity-distance curve"* (coördinates being taken as in *Fig. 1*).

Proof.—If in eq. (3) above we substitute the values $v = nx$ and $dv = n\,dx$, we obtain

$$p = n^2x\,\frac{dx}{ds}.$$

But, drawing through q the tangent line qT, and a right line qB parallel to OS; and also forming the elementary right triangle whose short sides are the increments ds and dx; we note that $dx \div ds = \tan\theta$; whence

$$p = n^2x\tan\theta, = n^2 \times \overline{mN}, = n^2u; \qquad (4)$$

(the angle TqB being $= mqN$, and the length of the subnormal mN being denoted by u).

If M is the mass of the material point or small body, the resultant force P at this instant has a value

$$P, = Mp, = Mn^2 u; \tag{5}$$

this resultant force, therefore, as well as the acceleration, can be represented by the subnormal. Putting, then, an arrow-head at N we have in mN a representative of the resultant force, *both in amount and position.* At a point of the path, such as m', where the velocity is diminishing, the subnormal is negative, mN', as shown in *Fig. 1;* and correspondingly the resultant force is also negative (*i. e.*, a retarding force).

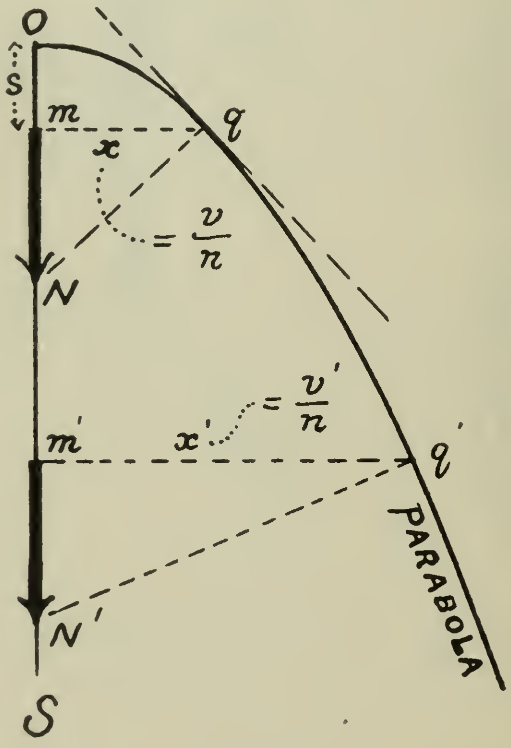

FIG. 2.

The advantage, then, of this construction is that we obtain at any point m of the path a measure of the acceleration, and also of the accelerating force (resultant), in the form of an arrow of a proper length, and *also of a proper position,* to represent that force as applied to the body at m. Even if the ordinates and normals are not actually drawn, in glancing along the curve the eye can judge approximately as to the variation of the accelerating force by estimating the magnitudes and positions of the successive subnormals. The following applications will be made :

(1) *Free Fall in Vacuo.—Fig. 2.* In this familiar case of motion, since the resultant force is constant, we know the acceleration to be the same or constant at all points, *i. e.*, equal to g, that of gravity. From mechanics we have for this case, $v^2 = 2gs$; *i. e.*, the "velocity-distance curve" is a parabola ; as it ought to be, since from analytics we know that the subnormal of a parabola is constant. That is, at m we find a subnormal u equal to that, u', obtained at any other point, as at m'.

(2) For a *uniform motion* along OS (*i. e.*, velocity constant) the curve becomes a right line parallel to the axis or path OS, and evidently the subnormal is zero at all points, as should be the case, since the accelerating or resultant force must be zero at all points if the velocity is not to change.

(3) If the *velocity is to increase in direct proportion to the distance* s of the body from O, the "velocity-distance curve" again becomes a right line, not parallel to the path, however, but intersecting it in O. Here, obviously, from the law of change of the subnormal, an accelerating force must be provided directly proportional to the distance s and having the *same sign*.

(4) *Harmonic Motion.*—(As is well known, the motion of the piston of a steam engine having a massive fly wheel and a long connecting rod is very nearly harmonic.) The principal property of this periodic, oscillatory, rectilinear motion is that the acceleration is proportional (but of *opposite sign*) to the "displacement" or distance (s) from the middle O of the oscillation.

In *Fig. 3* let O be the middle of the oscillation, D and C the extreme points. Denote $OD, = CD$, by r, and the velocity of the body each time it passes O (either up or down) by c. Let m be any position of the body going down. The circle (since all normals pass through the centre) is a curve in which the subnormal is evidently identical with the abscissa (except that it is of *contrary sign*) and hence proportional to it ; of course, the origin being at the centre. Hence it is immediately apparent, from the above property of harmonic motion, that if a circle be described with O as a centre and radius equal to r, it will be a "velocity-distance curve" for the harmonic motion; with a scale-number $n = c \div r$, since the radius OE ($= OD = r$) is to represent the velocity c.

(An ellipse, also, would serve as a velocity-distance curve, the subnormal being proportional to, though not coinciding with, the abscissa, and of opposite sign; but, aside from its simplicity of construction, the circle has a peculiar advantage, as will be seen, in representing the *time* of reaching any point.)

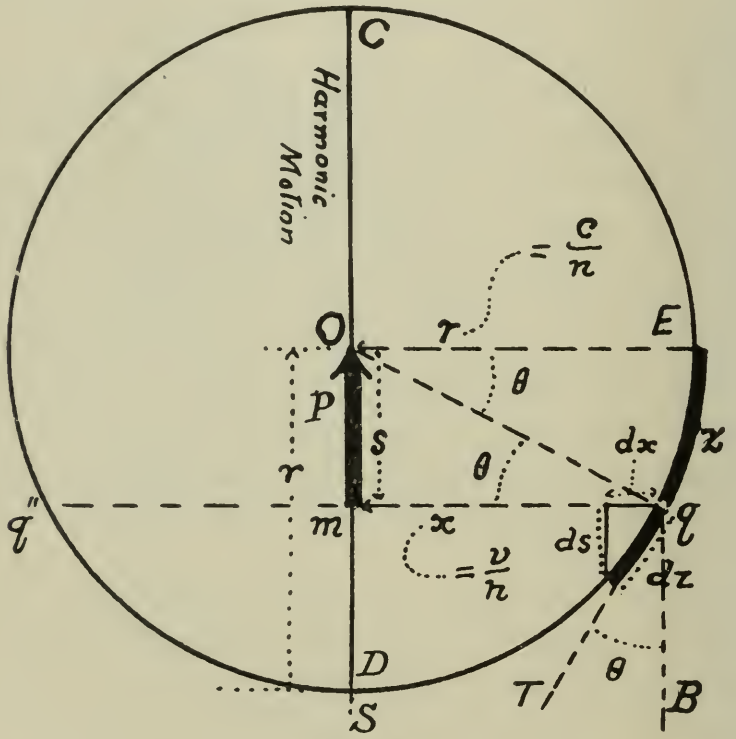

FIG. 3.

The above circle being drawn, the subnormal u for any point m of the path, is equal to the abscissa s with its sign changed, whence the acceleration is

$$p = n^2 u = n^2 \times \overline{Om} = - n^2 s, = n^2 r \sin \theta = \frac{c^2}{r} \sin \theta$$

while the velocity at m is

$$v = n\, x = \frac{c}{r}\, x \left(\text{so that } av = \frac{cdx}{r}\right)$$

(The left-hand half of the circle pertains to the upward return motion.) In this case we find the peculiar feature that the *time* (t) occupied by the body in passing from O to any point m is proportional to the length of curve z from E to q, which is proved as follows:

Inserting the above values of p and dv in the fundamental relation—

$$p = \frac{dv}{dt},$$

there results

$$dt = \frac{dx}{sin\ \theta} \cdot \frac{1}{c} = \frac{dz}{c},$$

where dz is the hypothenuse of this elementary right triangle at q. But this gives

$$\frac{dz}{dt} = c. \tag{6}$$

That is, the velocity ($dz \div dt$) of a point q imagined to move along the curve from E and always keeping in the horizontal through the material point m as the latter moves along $O \ldots S$, is *constant*, $= c$. Hence the time (t) occupied by the body in passing from O to any other point m of its path must be the same as that necessary for the imaginary point q to describe the linear arc $E \ldots q, = z$, with a *constant velocity* $= c$; therefore the time $t = (lin\ arc\ Eq) \div c$. For instance, the time of passage from O to the extreme point D is

$$t_D = \left(\frac{\pi\, r}{2}\right) \div c = \frac{\pi}{2} \cdot \frac{r}{c};$$

so that for a complete cycle or period the time

$$= \frac{2\, \pi\, r}{c}.$$

Also, to pass from O to D and up again to m, requires a time

$$= \frac{lin\ arc\ E\ D\ q''}{c}.$$

Evidently, to secure this motion, the body having the initial velocity c at O, the resultant force must always point toward O and be caused to vary in proportion to the displacement s; its absolute value at D, *e. g.*, being

$$P_{\mathrm{D}} = Mn^2 u_{\mathrm{D}} = Mn^2 r = \frac{Mc^2}{r}.$$

That is, at any point m it must have a value

$$P = Mn^2 u = \frac{Mc^2}{r^2} \cdot \frac{s}{r}.$$

(5) *Free Fall with Air-resistance.*—As an example where a practical application can be made of the foregoing property

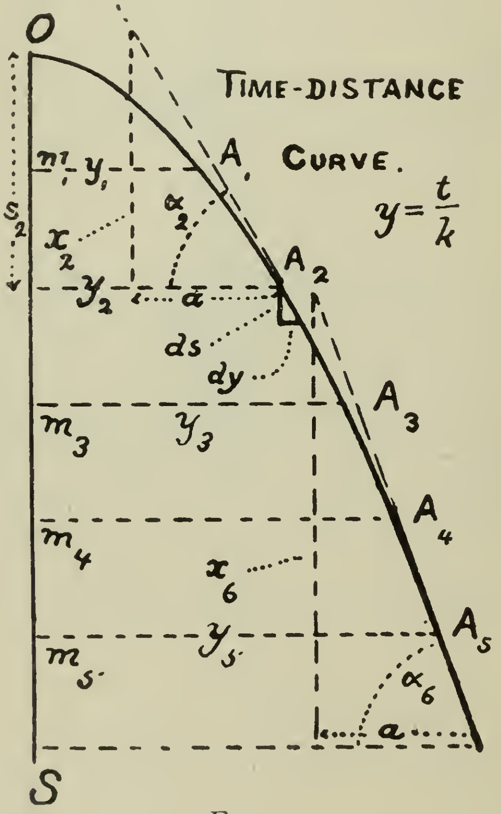

FIG. 4.

of the subnormal in a velocity-distance curve, let us suppose that experiments have been made in the laboratory (with a tuning-fork chronograph, electric signals, etc.), with the vertical free fall, in the atmosphere, of a body of such comparatively large bulk and small mass as to meet with considerable resistance from the air; and that it is desired, by means of the measured times of reaching six successive points in the vertical path, to determine graphically the resistance of the air at each point, and hence the dependence of this resistance on the velocity. The body having started from rest at *O*, *Fig. 4*, let s_1, s_2, s_3, etc., be the respective distances from *O* of the six points, m_1, m_2, m_3, etc., and t_1, t_2, etc., the observed times (all reckoned from the instant of leaving *O*). Selecting a convenient scale-number *k* for the times (*e. g.*, with the foot and second, $k = 5$ signifies that one foot of ordinate represents five seconds of time) plot the six horizontal ordinates $y = t_1 \div k$, $y_2 = t_2 \div k$, etc.; (in general $ky = t$ and

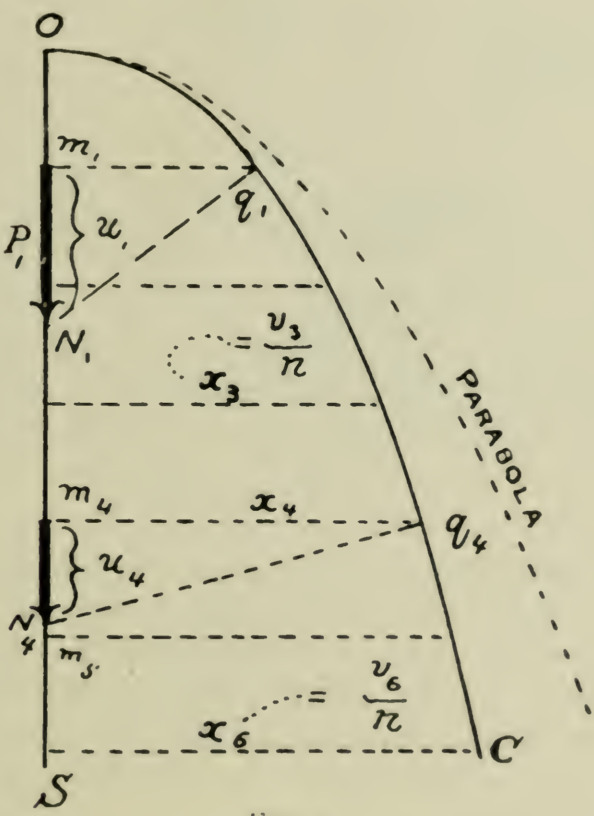

FIG. 5.

$dt = k\,dy$). Through *O* and the six points last determined, and A_1, A_2, etc., draw carefully a smooth curve, and at each of the six points a tangent line; and also from each point lay off to the left, along the ordinate, a convenient distance *a*, the same for all, through whose left-hand extremity draw a parallel to *O. . . S* to meet the corresponding tangent line and thus determine six vertical distances x_1, x_2, etc., proportional to the velocities of the body as it passed the respective points m_1, m_2, etc.

(For in general, at any point, of this "time-distance curve," we have

$$x = a \ tan \ \alpha = a \cdot \frac{ds}{dy} = ak \frac{ds}{dt} = a \ k \ v).$$

With the same points m as before on the axis $O \ldots S$, now plot the successive x's as horizontal ordinates (*Fig. 5*) and thus obtain points q_1, q_2, etc., on a "velocity-distance curve" OC (since these x's are proportional to the velocities; the scale-number implied in their use as ordinates being

$$n = \frac{1}{ak};$$

for nx $(= v)$ must

$$= \frac{x}{ak}$$

from above). A smooth curve OC is now to be drawn and the six subnormals constructed. The latter are proportional to the values of the respective resultant forces at the six points m_1, m_2, etc. For instance, if u is the length (in feet, say; the foot and second having been in use) of the subnormal for m_1, the resultant force at m_1 [from eq. (5)] is

$$P_1 = Mn^2u_1 = \frac{Mu_1}{a^2k^2}.$$

At each lower point the value of P is smaller, as the air-resistance increases with increasing velocity. Since the body's weight G acting downward, and the air-resistance R acting upward, are the only forces actually exerted on the body the (ideal) downward resultant P is equal to the excess of the former over the latter, *i. e.*, $P = G - R$; whence we have, at any point m,

$$R = G - \frac{Mu}{a^2k^2}. \tag{7}$$

As to the dependence of the air-resistance R on some definite power of the velocity, further computations or graphic operations can be undertaken in an obvious manner.

Fig. 5 also shows (dotted) the parabola, or curve of constant subnormal, which would be obtained as the velocity-distance curve corresponding to a free fall in vacuo (plotted with the same value of n).

THE PORT OF PHILADELPHIA.

By Prof. Lewis M. Haupt, C. E., University of Pennsylvania.

[*A lecture delivered before the Franklin Institute, November 20, 1891.*]

Some cities, like some men, are born great, while others have greatness thrust upon them.

Philadelphia was destined to attain greatness from her infancy. Her founders were not mere adventurers, but men of firm religious convictions, who found on the shores of the majestic Delaware a refuge from persecution. Here the intrepid Swede, the adventurous Dane, the philosophic German and the conscientious Quaker dwelt together in brotherly love.

The site of the city was carefully selected by William Penn, with reference to its adaptability to the wants of a large community. Its facility of access by the means then available, its harbor, its topography, its sources of supply of food, water and fuel, fish, game and timber, were all duly considered, and so wisely was the site chosen that for 144 years Philadelphia maintained her supremacy over all the cities of the new world. Her ships covered the seas, her "conestogas" traversed the mountains, her manufactures supplied the most distant markets, while her intelligence and public-spirited patriotism made her the cynosure of the world.

In 1820, five years prior to the opening of the Erie Canal, Philadelphia had a population of 135,673, being 11,931 more than that of New York. In 1830, five years after the opening, there was a balance of 8,325 in favor of New York, and this difference has been constantly increasing to date. In 1840 it was 54,673 more; in 1850, 106,785; in 1860, 248,140; in 1870, 268,270; in 1880, 359,039 and in 1890, 468,649, showing a rapid rate of increase.

The city of Chicago was chartered in 1837, with 4,170 inhabitants. At the date of the last census its population was 1,098,576, or 53,682 more than that of Philadelphia. Thus, in a half century this interior port has outstripped her two-century-old sister.

The opening of the Erie Canal caused a decline in the commerce of Philadelphia, while it greatly stimulated that of New York, since it increased immensely the territory tributary to that centre. It did not violate the general law relative to the location of the proper site for our city, viz: at the point of transfer between land and water carriage, or at the head of navigation, but it modified the conditions and enabled both New York and Chicago to surpass us, in consequence of their terminal positions, on a line of less resistance, reaching a larger territory.

The reason for the locus of transfer being found at the head of navigation for ocean vessels, will become apparent upon a moment's reflection. While land and water traffic are reciprocal, it must be remembered that the water produces comparatively nothing while the cost of movement over it is much less than that on land. Hence the more land there is surrounding a navigable channel to the sea, the greater will be the commerce. A city on the border of an extended and straight coast-line, as Norfolk, for instance, will have but a semi-circular area to draw from; one which is on a reëntrant angle, like New York, will have three-fourths of the circle tributary to her port; while one that is in the heart of a continent, as Chicago, will have nearly the full circle, and hence for equal land rates of transportation and an equivalent population, the latter will have a great advantage as a shipping point. If there were a deep draught channel from Chicago to the sea, whereby the break of bulk at Buffalo and New York might be avoided, the water rate would be still lower, and the advantage of the terminals be even greater.

Substantially the same conditions exist at Superior and Duluth since the enlargement of the Sault St. Mary Canal, excepting that a portion of the tributary area is on foreign territory. Thus the geographical position of the port is seen to be an important factor in determining the amount of its commerce, but there are other elements which materially affect this movement. One of these is the cost of land transportation. This is a function of the number and character of the ways of communication. The more railroads and highways there are radiating from the port, the lower will be the tariff, provided the roads and rolling stock are maintained in good condition as competing lines. In this particular New York and Chicago outstrip Philadelphia in about the ratio of six to one.

Cheap transportation to and from the back country is therefore another of the ruling factors in determining the amount of commerce of a port, since it expands or contracts the tributary areas inversely as the square of the rate fluctuates.

It behooves us, therefore, as citizens, to consider whether it is not possible to extend the tributary territory of this point by reducing the rate of traffic or by increasing our facilities for reaching a much larger constituency, for patronage is the life of trade, and the transportation lines are the tentacles whereby this life is maintained.

The transportation routes tributary to Philadelphia are the lines owned, controlled, leased or operated by the Pennsylvania Railroad Company, which embrace (1890):

	First Track. Miles.
The United Railroads of New Jersey, ...	445·69
New York and Long Branch Railroad, ...	38·04
Pennsylvania Railroad (Main Line), ...	1,441·37
Philadelphia and Erie, ...	549·31
Northern Central, ...	382·45
Junction Railroad in Philadelphia, ...	3·56
Philadelphia, Wilmington and Baltimore, ...	648·08
New York, Philadelphia and Norfolk, ...	111·46
West Jersey, ...	222·01
Camden and Atlantic, ...	80·49
Cumberland Valley, ...	164·74
Allegheny Valley, ...	259·40
	4,346·60
Total trackage in Pennsylvania, including sidings, etc.,	8,288·14

In addition to this there are the following lines under the jurisdiction of the "Pennsylvania Company," having its headquarters at Pittsburgh, and coöperating with the Pennsylvania Railroad:

		Miles.
The Pittsburgh, Fort Wayne and Chicago,	469·9	
Branches,	352·4	
Leased lines,	338·9	
		1,161·2
Operated by control of stocks:		
Pittsburgh, Cincinnati, Chicago and St. Louis,	1,144·5	
Its branches,	247·7	
Other lines,	445·9	
		1,838·1
By guarantees of Pennsylvania Railroad Company,		491·1
		3,490·4
Mileage of Pennsylvania Railroad brought forward,		4,346·6
Total mileage under control of Pennsylvania Railroad,		7,837·0

The Philadelphia and Reading system embraces under its control a total of 1,106·6 miles, and carried in 1890, of coal, 10,821,691 gross tons; of miscellaneous freight, 10,968,536 gross tons: and, including the weight of passengers, a total of 24,788,527 tons, the number of passengers being 18,103,893.

The Lehigh Valley Railroad Company's lines connecting Lake Ontario at Fairhaven with New York and Philadelphia, cover a distance of 886·24 miles. This company's business is reported for 1890 to have been:

Passengers,	5,191,821
Miscellaneous freight (gross tons),	5,358,064
Coal,	9,101,824

The Lehigh Coal and Navigation Company have, of railroads (leased to Central Railroad of New Jersey), 192·49 miles; of canals (leased to Central Railroad of New Jersey), 108 miles.

The Baltimore and Ohio Railroad embraces:

	Miles.
Main Line to Wheeling	379·80
Branches of Main Line,	391·15
Philadelphia Division,	124·00
Pittsburgh Division,	335·60
New York Division,	5·05
Trans-Ohio,	647·58
Valley Railroad of Virginia,	62·00
Ohio River Bridge,	2·50
	1,948·13

It connects Chicago, Cleveland, Sandusky and Cincinnati with Baltimore, Philadelphia and New York. On the 1,212 miles east of the Ohio it carried, in 1890, 11,469,091 passengers and 25,652,284 tons of freight. Of these 2,529,335 passengers and 5,882,289 tons were moved over the Philadelphia Division.

Thus while the mileage of these four trunk lines aggregates 11,970 miles, it does not mean that it is all tributary to Philadelphia. On the contrary it is divided mainly between New York, Philadelphia and Baltimore as well as its western terminals, and the percentage of traffic going to each is determined largely by the local facilities, rates, demand, policy and interests of the transporting companies. That the *pro rata* coming to Philadelphia is small, will be evident from her commercial statistics as compared with those of the other Atlantic ports.

Thus the value of the exports of breadstuffs, provisions and mineral oils for the year ending June 30, 1891, are reported as follows, from

	New York	Baltimore	Boston.	Philadelphia.
	$109,825,000	$40,544,000	[illegible]	$19,[illegible]
Ratio,	5·5	[illegible]	1·4	1

From which it appears that, while Philadelphia is as near to the sources of these staples as any of the four ports on the Atlantic, she cannot compete even with so distant a point as Boston, which shipped more than three times the quantity of breadstuffs and provisions that Philadelphia did.

As the New England States are not producers of these articles, but consumers, the bulk of the freights originating in the West must have gone by water past New York and up the Sound to Boston before it could be exported. The opening of the Cape Cod Canal will still further stimulate this trade and make the discrepancy of our local exports even greater, unless measures are taken to counteract this influence.

Again, if we compare the *total exports* of the four ports we will find Philadelphia far in the rear. For 1890 the exports from New York, Boston, Philadelphia and Baltimore, were:

	New York.	Baltimore.	Boston.	Philadelphia.
Foreign.	$15,845,974	$22,941	$836,989	$170,863
Domestic, ...	370,322,430	73,967,796	70,364,955	37,241,645
Total exports, . . .	$,86,168,404	$73,990,737	$71 201.954	$37,412,508
Ratios referred to Phila.,	10 3	1·99	1·9	1

In 1887 these relations were 10, 1·5, 1·7, 1; in other words, the export trade of Baltimore and Boston have increased more rapidly than that of Philadelphia and are actually nearly double that of this city, although the population of either of those places is less than half that of this port.

May we not inquire, of what avail is it to be the largest manufacturing centre in the United States and what becomes of our products? Are they sent to other ports for shipment, thus increasing their cost to the consumer or adding to the expense of the producer? As well might we expect freight to be hauled by rail from Baltimore to Philadelphia to be shipped, as from Philadelphia to New York for the same purpose. The great discrepancy between New York and Philadelphia is certainly not due to differences in population, nor in manufactures, nor to geographical position, nor to relative proximity to the source of the great staples composing the bulk of the commerce, coal, wheat, oil, sugar and textiles, for in these respects the two cities are far within the limits of their commercial ratio of of one to ten.

No matter in what direction we look for the cause of this great discrepancy, we are forced to the conviction that for some inexplicable reason the "common carriers" find it subservient to certain interests to deliver the bulk of their freights at other terminals than those on the Delaware; for there is no mechanical or physical law that will justify a movement over a line of greater resistance rather than over the lesser one, provided it have equal facilities for storage and trans-shipment.

This general statement is confirmed by a glance at the statistics of the *grain exports* of New York, Baltimore, Boston and Philadelphia for the past few years.

Exports of wheat and corn from

	New York	Baltimore.	Boston.	Philadelphia.
1887, ...	54,192,321	18,175,104	6,297,083	10,770,737
1888, ...	26,845,423	7,824,422	4,456,480	1,800,215
1889, ...	39,571,280	21,212,598	7,595,044	4,750,022
1890, ...	37,169,433	24,250,597	5,025,990	17,353,307

The logic of these figures shows that in 1888 and 1889 this port shipped barely one-half as much wheat and corn as Boston, seventy-eight per cent. less than Baltimore and only one-eleventh that of New York, yet this was not due to any differential rates favoring the more remote ports, for the following were the tariffs as published for 1889,* all rail, from Chicago to

	New York	Phila.	Balto.	Boston.	To Liverpool. Average.	Cwt.	Chicago & Lake Erie Canal Charges to New York (including Buffalo.)
Flour, per barrel, . .	50	46	44	60	—	—	
Grain per 100 lbs., . .	25	23	22	30	29½	12-3/4	7 5-8 cts. per bu. (60 lbs.)
Provisions per 100 bbls.,	30	28	27	35	57½	—	
Corn per 100 lbs., . .	20	18	17	25	—	—	

Showing that it cost four cents more per pound for flour by rail to New York, and sixteen cents more to Boston than to this city. For grain the differences are also in our favor, viz: two cents per hundredweight to New York, and seven cents to Boston. Hence, if there were no disturbing causes, the law of distribution over the lines of least resistance, as measured by the cost of movement, should bring the bulk of the grain to Baltimore and Philadelphia, rather than to New York and Boston. But when it is seen that the through rate by the lakes and the Erie canal, including the Buffalo charges, is only *one-half* the all-rail rates to New York it explains the anomaly, and shows why even Boston can export more than Philadelphia, and it forcibly points the moral as to the importance of maintaining the waterways for the public welfare. I have frequently urged the importance to Philadelphia of a more direct and enlarged artificial channel between this city and New York, by way of the Upper Delaware River, and the Delaware and Raritan Canal, thus extending the benefits derived from the Erie Canal to Philadelphia, and rendering it possible to bring that powerful auxiliary into competition with our railroads for the interior traffic of the country. Even should the traffic not be large over the canal, the facilities would be there and the moral effect would be to keep rates low and greatly to augment the business. I believe this one project would have a greater beneficial effect on the commerce of this entire section of country than the building of half-a-dozen trunk lines of railroad. There is no part of the civilized world where such a canal is more greatly needed, or where it would give greater promise of success. Its termini would connect a population equal to one-tenth that of the entire United States, and as I have elsewhere proven,* it would be beneficial to the railroads skirting its territory. No other canal across New Jersey would pay in competition with the river as it would take too long to pass through it.

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* *Thirty second Annual Report, Trade and Commerce of Chicago.*

But the low water rates *via* the Erie Canal are not alone responsible for the decadence of this port. A few statistics relative to the movement of *grain cars* will also be found suggestive. Thus the car receipts for 1890, at New York, were as follows:

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* Pamphlet, *The Commercial Paradox*, from *The Manufacturer*. By L. M. Haupt, Philadelphia.

	N.Y.C.	W Shore.	Erie.	P.R.R.	D.L.&W	L V R R	Total
1890, ...	8,866	15,105	19,732	3,545	4,276	11,628	63,152
1891 to October 16th, ...	23,618	16,601	22,272	1,833	1,157	9,697	75,178

Thus the New York Central and West Shore, although longer than the Erie, moved, up to October 16th of this year, 40,219 cars, as compared with 22,272 over the Erie, and only 1,833 over the Pennsylvania Railroad. The business of the Lehigh Valley road in grain to New York is, by this exhibit, five times greater than that of the Pennsylvania Railroad.

The data for Philadelphia and Baltimore are:

	CARS MOVED TO PHILADELPHIA.			TO BALTIMORE		
	P. R. R.	P. & R.	Total.	P. R. R.	B & O.	Total.
1890, ...	18,276	9,492	27,768	17,662	17,495	35,157
to October 16, 1891, .	6,138	5,058	11,196	10,672	12,248	22,920
Total loss, . .		. . . . .	16,562	Total, ...		12,237

This shows a remarkable falling off in the grain movements to date for both of these ports. The Pennsylvania Railroad has 12,138 cars less for Philadelphia to date, October 16, 1891, than it had for the whole of last year, and 6,990 less for Baltimore. The Philadelphia and Reading Railroad has 4,434 cars less for this point, and the Baltimore and Ohio 5,247 less for Baltimore. The total losses are 16,562 cars for Philadelphia, and 12,237 for Baltimore, or for both places, 28,799 cars. The gain in New York has been 12,026 cars, and it is worthy of note that by far the largest gain on any of the railroads was that on the New York Central and West Shore (16,248 cars), and which *parallels the canal and Hudson River.* Surely this waterway does not appear to have injured these railroads. Why so large a percentage of the grain movement should have taken the longer northern route, and the business of the lines leading to these nearer terminals should have so greatly fallen off in this year of plenty, must be left, for the present, largely to conjecture. It is sufficient to state the facts: Thus from January 1st to October 2d, the exports of wheat and corn from Philadelphia amounted to 5,856,286 bushels as compared with 17,110,154 bushels for the same period of last year, a loss of 11,253,868 bushels,* or 337,616 tons. For Baltimore the figures for this year are 13,610,706 bushels, as compared with 23,526,908 for last year, being a loss of 9,916,202, which is not quite so great a reduction as here. While for New York the exports of wheat and corn for the nine months ending October 2, 1890 and 1891, were 32,658,859 and 36,163,427 bushels, respectively, being a gain of 3,504,568 bushels. New York's percentage for this period of 1891 was 47; Baltimore's, 18; New Orleans', 11; Montreal's, 9; Philadelphia's, 7, and the balance scattering. In 1890 our proportion of this trade was sixteen per cent. From whatever standpoint we view the commercial statistics, therefore, we find Philadelphia occupying the lowest position amongst her rival ports.

THE PETROLEUM MOVEMENT.

Let us look for a moment at another of the staple exports of the country which to-day is practically independent of any of the laws of competition in transportation. I refer to petroleum. There are pipe lines under the same management reaching from the oil centre to each of the three ports, New York, Philadelphia and Baltimore, and although the line to the last-named point is perhaps a little shorter than either of the others, the cost of transportation is virtually the same, hence the amount of exports may be taken as furnishing some indication of the relative importance of the port facilities for foreign exports.

The shipments for 1890, were, from New York, 8,871,059 barrels; Philadelphia, 3,185,924 barrels; Baltimore, 288,643 barrels. Total, 12,335,626 barrels, of which the percentages were: New York, 71·92; Philadelphia, 25·82; Baltimore,

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* "The loading capacity of the 60,000-pound car varies from 850 to 900 bushels for wheat; from 850 to 1,000 bushels for corn, and from 1,200 to 1,500 bushels for oats." Average increase, oats, 1,050.

2·26, but so great were the facilities offered for the product at this port that a new line was put into operation here, February 27, 1891, and the percentage of oil sent out has now risen to 33·67, while that of New York has fallen to 64·51, and of Baltimore to 1·82.

These figures would seem to justify a much higher rank to this port than is generally accorded her on the commercial registers, and go far towards showing that the decadence of the commerce is not due so much to physical obstructions to navigation nor to geographical position, as to the manner in which the freight movements are regulated by those having control of them. For the lake and rail traffic Philadelphia has advantages not possessed by any other port, since, from Erie, the rail distance is but 446, while to New York from Buffalo *via* the New York Central is 442 miles, and by the Erie Railroad it is 423 miles. From Erie to Baltimore is 426 miles or only 20 miles less than to Philadelphia, but the former is much further from the sea than the latter, and hence the desire for a ship canal across the Peninsula to Delaware Bay. Erie is also nearer the source of freight than Buffalo and has a more capacious harbor.

In this connection one of the most experienced observers in the United States says:*

"The city of Philadelphia has superior internal communications with the entire country lying west of her boundaries. The traffic produced and exported to foreign countries by that large area of territory, and that which it imports, can, so far as promptness and cheapness of transportation are concerned, be better done through Philadelphia than through any other Atlantic port, because the Delaware River permits the water portion of the through carriage to continue so much further inland than any other port having equal rail and lake connections with the great West."

The superiority of the site is indisputable, and has been demonstrated by experience, but, as has been shown, the conditions of trade are unfavorable, and Philadelphia ranks among the least of the principal commercial centres of the country. The existence or non-existence of the islands in the Delaware, about which so much has been said, is a comparatively unimportant factor in the case. Their removal, which is estimated to cost $3,500,000, will not change the policy of the transportation companies towards this city. It will, however, permit the extension of the piers and bulkheads eastward and thus provide greater facilities for transfer of freight, which is very desirable, but it must also be remembered that to provide for a rapid delivery and removal of freight there must be a coincident arrival of ship and cars or else a sufficient storage capacity to provide for the delay or shortage of either. To reach the Delaware front, the freights must be hauled across the city *via* Willow Street or Washington Avenue, or else by a long detour *via* Greenwich Point or Port Richmond. Each ship carrying 3,000 tons of cargo would require 100 thirty-ton car-loads of freight, and at three cars per 100 feet the length of each train for loading and unloading would be 3,300 feet, or a total of about three-fifths of a mile. But the cars do not run full, and hence the train would, in fact, be longer. At present provision is made for the grain business at Richmond and Girard Point, where there is elevator capacity amounting to about 3,000,000 bushels or about thirty vessel loads, but a visitor to Girard Point would be apt to conclude from the absence of vessels and the general appearance of the vicinity that the company had gone out of business.

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* Col. Jos. D. Potts.

What is required to stimulate commerce and to restore to Philadelphia a portion of her old-time activity, is an element which will enable her merchants, manufacturers, shippers, producers and consumers alike to obtain their supplies or ship their products over lines which are virtually independent of combinations, and there is nothing that approaches so near to fulfilling this condition as the waterway. There is the river it is true, but it opens upon the sea, its inland territory is limited to the few miles to Trenton, and even that is restricted by the Five-Mile Bar, which is being improved at Fisher's Point. But if the barrier which has checked the trade with the interior *via* the Erie and Delaware and

Raritan Canals were removed, and the northern waterway opened across New Jersey *via* an enlarged ship canal between Bordentown and New Brunswick, it would do more, I believe, to develop all classes of business and trade in this, as well as other cities, than any project that could be undertaken. The Pennsylvania Railroad Company has leased the Delaware and Raritan Canal for a period of 999 years, guaranteeing ten per cent. interest on a capitalized value of $5,847,400. In 1890, the freights moved over it amounted to 1,209,668 tons. The gross receipts were $509,162.76, and the expenses $415,326.08, giving net receipts on the business transacted $93,836.68, but with the interest and taxes the total losses for the year amounted to $565,435.56, or over $500,000.

Contrasting this with the business done in 1866, its most prosperous year prior to the lease, we find expenses, $360,513.83; receipts, $1,294,156.69; profits, $933,642.86, which was nearly twenty-three per cent. of the capital invested in the canal ($4,381,251.28), while for the same year the Camden and Amboy Railroad barely earned five per cent. on its capital of $10,099,000.97. At present a large amount of the coal to eastern ports goes out by the Capes in colliers, which if the canal were enlarged, could save considerable time by traversing it. The grain and ores of the lake region could also be delivered in this city at less cost than at present and the stimulus given to trade and population would rapidly compensate the railroads for any temporary loss they might suffer from a diversion of a portion of the traffic. Such is believed to be the lesson of experience elsewhere.

If the cost of this line were to amount to $20,000,000, a traffic of only 2,000,000 of tons at fifty cents per ton, which is believed to be considerably less than the present rate by water, would pay five per cent. on the cost, and this traffic is less than the average for a number of years prior to the lease of June, 1871. Can Philadelphia afford to wait 979 years for a consummation so devoutly to be wished? But this is a project of national importance and has been frequently urged from the foundation of the Republic. It was one of the features of the great log rolling bill introduced into Congress in 1812, in behalf of national aid for the Erie Canal, and has been frequently revived and urged by various interests, but as yet without success. Under existing methods of administration it will require the united influence of the Atlantic Coast States as well as of those along the Great Belt waterway, all of which will be benefited, to induce the Government to inaugurate the undertaking. It is certainly worthy the effort.

I have placed this enterprise first in importance because I believe it will produce the greatest amount of good, both locally and generally, but I would not ignore those works of lesser importance which are distinctly within the jurisdiction of the municipality or of the individual. Unfortunately there has been too little concerted action on the part of our citizens in the way of public improvements, and it is only when aroused by some threatened or actual calamity that sufficient interest can be awakened to prevent it.

After a long contest the Baltimore and Ohio Railroad was admitted and the Reading Terminal and the Belt Line ordinances were passed. The work on them is now well begun. They will no doubt be of great use to the city and its commerce in facilitating traffic and aiding in the general distribution of freight, but their effects are, to a large extent, local. They will enable the few competing land carriers to reach their principal patrons, but they do not very materially increase the territory tributary to the city or reduce the rates of transportation, as would be the case with the proposed waterway if under national control or even under a corporate body charging a limited tariff.

Although much time has been given to the commercial aspects of this question rather than to the physical, it seems to be necessary, to awaken if possible, a greater public interest in its importance and to concentrate attention upon its political relations, for it should certainly be fostered by the Government, but this will only happen when the wish of the people is made manifest by instructions to their representatives.

PHYSICAL CONDITION OF THE PORT.

Although the water frontage of this city is about twenty-five miles in length only a small portion of it has been developed, a large portion being Government property and other portions being cut off by the Five Mile and Horseshoe Bars. Immediately in front of the city the stream is occupied by Smith's and Windmill Islands, which have recently been purchased, at a cost of $708,652.86. The contract for their removal was let last spring and is progressing slowly. As the question is often asked whether this improvement will be permanent it may be stated that the mere removal of the islands without a simultaneous contraction of the river banks so as to maintain a constant cross-section, will result in hastening the deposits by reducing the velocity of the stream. As this formation is one produced by the river and is situated on the middle ground between the paths of the flood and ebb currents, it is the natural dumping ground of the stream and unless there be some auxiliary work to bring those two currents more nearly into coincidence, the bar must ever remain.

But there is no provision in law requiring the riparian owners to extend their piers to the new Port Warden's line which has been recently established by the Secretary of War and which lies in the deep water of the main channel. Unless this work is done at a number of points at the same time with the removal of the islands, the amount of material to be dredged will be found to be largely in excess of that now in place and the desired result will be very much delayed, as well as the expense increased.

Recent specifications provide that "the rate of progress of the excavation is to be determined by the rate of advance of actual wharf constructions to the new harbor lines so as to maintain the assigned section of the new channel." But as there is no law requiring property owners to extend their wharves into water from forty to nearly sixty feet deep, and as none have done so, it would seem that the work of excavation should be suspended, as it has been for some time past, though it is believed from a different cause.*

* This should not be misunderstood to mean an official suspension by the Government, which at this date has not been ordered. L. M. H.

Moreover the jurisdiction over the harbor lines appears now to be vested by Act of Congress, in the Secretary of War; by Act of Assembly, in the Board of Port Wardens, subject to ordinance of City Councils, and the Board's authority in this matter is restricted to granting permits and is not mandatory as to constructions or extensions of piers.

Again, there is another body, the Board of Harbor Commissioners, appointed by the Presidents of Select and Common Councils, under an ordinance of the city passed July 8, 1879, whose duty it is to "devise, consider and present a plan or plans for the preservation and permanent improvement of the harbor and the port of Philadelphia, and for the increase of its landing accommodations."* For a time this Board was assisted by an Advisory Board composed of an officer of the Engineer Corps U. S. A., an officer of the Navy, and an assistant from the Coast Survey, but this Advisory Board was recently disbanded. There is also a Board of three U. S. Engineers on the Permanent Improvement of the River, and a U. S. Engineer detailed by the Secretary of War as Consulting Engineer to the Harbor Commissioners in lieu of the Advisory Board.

Thus there would appear to be ample provision for the making of plans, but virtually none for their execution; excepting so far as the navigable channel is concerned or as it may be found to be to the interest of the private owner to improve his property subject to restrictions as to length. It must be evident, therefore, that before a well-digested plan for the improvement of our Delaware River front can be executed, there should be authority vested in some central body to condemn and purchase property, and to build and lease such wharves and docks as may be necessary to conduct the business of trans-shipping freight.

As the vested interests along the river front are numerous and the properties very valuable it will be many years before such a symmetrical development may be expected, and there are other reasons why the consummation of a reorganized commerce at this point may be long deferred.

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* The writer is indebted to Wm. R. Tucker, Secretary of the Philadelphia Board of Trade, for this information.

On the other hand we are not devoid of resources, for there is as yet a comparatively undeveloped frontage, of great value, available near Greenwich Point on the Delaware, and on both banks of the Schuylkill, which flows through the heart of the city, where there are ample opportunities for developing commercial facilities far greater than those now existing and at a comparatively small cost. The principal railroads either have tracks laid to or are within a short distance of the mouth of the Schuylkill, and freight is daily carried past that point to the Delaware front only to be returned to the same point by water on its way to the Capes, thus doubling the haul and obstructing the city streets by the surface traffic. The Belt Line will bring this section within a few minutes' ride of the Custom House and even without it the Chester branch of the Philadelphia and Reading Railroad renders it possible to reach the business portion of the city in a very short time.

This would appear to be the section of the city best adapted to meet the commercial requirement of its immediate future, and I believe it will not be many years before very material improvements will be found there. It is not generally known that about one-third of the foreign commerce of this port goes out of the Schuylkill. It is not very long since one of the Allen Line steamers was nine days in getting through an ice pack on the Horseshoe shoals near League Island. Already the railroad companies are seeking terminals at Marcus Hook and Chester, beyond the city limits, and it certainly looks as if they intend to utilize these points at the expense of the city.

There is not time to review the physical condition of the Delaware River from its mouth to the port, but it is worthy of note that it is not all that could be desired, although, thanks to the prompt action of the Engineer in Charge, Major Raymond, its condition has been considerably ameliorated at one of its most dangerous points. Between February 22, 1890, and May 8, 1891, or in less than fifteen months, at least forty-eight vessels struck on or near the Bulkhead Shoals, and so serious had this obstruction become that in March last no less than seven steamers ran aground, two of which were detained nearly twelve hours.

A jetty is now being built there which it is expected will aid in keeping open the channel which has been deepened by dredging.*

There are several other points where the depth is barely sufficient, as at Dan Baker Shoal, Maiden Island Bar, Cherry Island Flats, etc., but taking it as a whole the river is regarded as one of the best waterways on the Atlantic, whether by day or night.

The Delaware Breakwater can no longer be regarded as a harbor, and the closing of the "gap" between the ice breaker and the breakwater, which is still in progress, will not materially enlarge its capacity or depth. The harbor has shoaled, from over twenty-five feet to less than seventeen. In some places near the breakwater only eleven feet are to be found. This is the inevitable result of all structures so located as to intercept the currents. Had the ice breaker been removed, as proposed ten years ago, and its material been deposited along the site of the gap, the result would have been a great improvement.

The term, harbor of refuge, is now a misnomer, for in the storm of March 12, 1888, no less than twenty-seven vessels which had sought shelter behind the breakwater were dashed to pieces and many lives were lost—and again in September of the year following, twenty-three vessels shared a similar fate, making fifty vessels lost in eighteen months.

The effect of the present structure will be to create an artificial island with a submerged embankment connecting it with the shore.

We have seen what the facilities are for bringing freight to our port by land and have discussed all too briefly the opportunities for handling such freight in transit. Let us now note the provision made for its transportation by water. This will be shown by giving the list of vessels engaged in the carrying trade to foreign or domestic ports from this city, as follows:

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* At the time of going to press it is unofficially stated that the single jetty at this point has given all the depth required for the largest vessels.

L. M. H.

There are eight foreign steamship lines at present running to this port, viz:

Line.	*To and from.*	*Number of Vessels.*	*Total net Tonnage.*
Allan Line, ...	Glasgow,	3	5.610
American Line, ...	Liverpool,	6	13.960
Atlantic Transport Line, ...	London,	7	13.853
Baltimore Fruit Company, ...	West India,	3	1.593
Howes Fruit Line, ...	West India,	3	1.241
North Atlantic Trident Line, . . .	London,	7	12,465
Red Star Line, ...	Antwerp,	2	4.486
Spreckels Line, ...	Hamburg,	4	5.490
		35	58,698 tons

Coastwise steamship lines number nine, as follows:

	Steamers.	*Net Tonnage.*
Boston and Philadelphia Steamship Line, . . .	4	4,264
Clyde Line, Richmond, Norfolk, etc., ...	5	3.588
Clyde Line, Philadelphia, Albany and Troy, . .	1	372
Clyde Line, Philadelphia and New York, ...	5	1,397
Ericsson Line (Baltimore), ...	5	1,483
Ocean Steamship Company, of Savannah, . . .	1	892
Philadelphia, Fall River and Providence Line, .	3	2.335
Philadelphia and New York (Mercer & Co.), . .	1	197
Phila. and Reading Coal and Iron S. S. Line, .	12	8,619
	37	22,897 tons

There is only one sailing vessel line running from this port; that is, Sutton's Despatch Line to San Francisco. During the past year eight ships have been chartered for this line comprising a net tonnage of 12,618.

These make a total of eight foreign lines of thirty-five vessels, carrying 58,698 net tons, and ten coastwise lines of forty-five vessels, carrying 35,515 tons.

By the way of comparing this with our sister city of New York, it is stated that in 1890 she had of—

	Vessels.	*Tons.*
Sailing vessels, ...	1,976	409,468
Steam vessels, ...	1,032	374,673
Total, ...	3,008	784,141

in addition to which there were 230 canal boats of 23,709 tons and 671 barges of 140,540 tons.[*]

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[*] John H. Gould, in *Scribner's Magazine*, November, 1891, "The Ocean Steamship as a Freight Carrier."

The canal boat business of Philadelphia is fast becoming extinct, although it was the cheapest method of bringing coal to this city, while the canal was maintained in good order.

Before the lease to the Philadelphia and Reading Railroad, July 1, 1870, the rate by canal was only one-half the subsequent rate by rail, and the canal paid.

Under the terms of this lease the railroad company agreed to guarantee the interest on the stock and bonds of the Schuylkill Navigation Company, amounting to $655,000 per annum, but in consequence of the policy of the railroad, and for other reasons, it went into the hands of receivers, and these guarantees were unfulfilled. The Navigation Company was subsequently asked to take back its property, but without any assurance that the railroad would furnish it with coal for transportation. Under these circumstances the request was of course declined. It was testified by the late President of the railroad company before the Master that all of the net revenues of the company up to that time had been earned by the canal. And yet this, the most profitable part of the company's property is allowed to fall into decay, while the more expensive method of transportation, viz: that by rail, is fostered at the expense of every coal consumer in this as well as other cities. The only party who can utilize this waterway for its legitimate purpose is the Reading Railroad Company, and such use of it would undoubtedly greatly increase the revenue of that company, as well as benefit the city at large.

The citizens of the port of Philadelphia have a direct pecuniary interest in the inquiry, Why does the Philadelphia and Reading Railroad Company desire to sell this dilapidated canal to the city as a conduit for the supply of water, rather than utilize it for the transportation of coal to this and other ports?

As the largest manufacturing centre on the continent, Philadelphia needs above all things cheap fuel, and debarred as she is from the use of natural gas, she is losing a number of industries which have been attracted to the gas belt. Her rate of growth during the last decade has been exceeded by almost every town or city of any size in the State. Thus while Pittsburgh has increased at the average rate of 5·26 per cent.; Pottstown, 15; Reading, 3·6; Scranton, 6·4; Shamokin, 7·6; Braddock, 15·8; Steelton, 27·8; Philadelphia's average yearly rate of increase is only 2·3 per cent.

This city has been considered fortunate in her location due to the proximity of this prime necessity—coal—but her vantage ground is destroyed by the improved lines of transportation to other cities and the development of new fields. Thus Chicago is abundantly supplied from the extensive deposits of Indiana and Illinois, and consumes more coal per capita than her Eastern rivals. In 1889, 4,665,258 tons were consumed in Chicago, of which more than two-thirds was bituminous, an average of 4·5 tons per individual.

New York	burned	5,153,436	tons, or	3·4	per capita.
Philadelphia	"	4,107,281	"	4·1	"
Brooklyn	"	2,000,000	"	2·5	"
Boston,	"	1,766,410	"	3·9	"
Baltimore,	"	1,108,613	"	2·5	"
Scranton, Pa.,	" only	132,145	"	1·8	"
Reading, Pa.,	"	391,846	"	6·7	"
Newark, N. J.,	"	544,076	"	3·0	"

The amount of coal delivered to vessels for their own fuel at the four ports was as follows:

For New York, ...	1,322,895	tons, . .	65 per cent. approx.
Philadelphia, ...	297,609	" . .	14 ±
Baltimore, ...	227,000	" . .	10 ±
Boston, ...	70,267	" . .	3 ±
Other Atlantic and Gulf,	80,000	" . .	3·8 ±
Pacific, ...	93,000	" . .	4·2 ±
	2,090,771		

These statistics barely need comment, they tell their own story, and show the importance to this city of creating and maintaining an unlimited supply of cheaper fuel for home consumption, manufactures and commerce, and this can best be done by a revival of interest in the Schuylkill Navigation Company's waterway, and an earnest popular appeal to the railroad companies which have throttled these cheap lines of communication on the flanks of this port, either to utilize these channels themselves or permit others to do so, for the public good. It appears to be the policy of the railroads to persist in transporting by rail when there are many articles of the grosser kind which could be carried much more cheaply and quite as expeditiously by water, thus producing a greater revenue for the transporting company, and at the same time reducing the cost to the consumer.

As patrons of these great companies may we not respectfully inquire why these facilities are not utilized to their fullest extent, for the benefit of all the parties at interest, and in the absence of a satisfactory explanation, urge upon the aforesaid companies the propriety of inaugurating a different policy whereby the waterways may be rehabilitated and employed to their full capacity. Then will the Port of Philadelphia be restored in large part to its old-time prestige.

The lecture was closed by projecting upon the screen a number of views of foreign and other harbors crowded with shipping, as at Marseilles, Trieste, Havre, Bordeaux, Liverpool, San Francisco, Boston and New York, and the plans of the Manchester and of the proposed ship canal from the Delaware River to New York Bay were exhibited. This latter project was so located as to avoid many of the difficulties incidental to an enlargement of the old Delaware and Raritan Canal and to shorten the distance from forty-four to thirty-three and three-fourths miles. There would be two lifts of twenty-five feet each and two tidal locks. The summit level would be fifty feet above mean low water, and the section of the canal is designed to be twenty feet deep by ninety feet bottom width, 150 feet surface width and ten feet bermes, giving about 26,000,000 cubic yards of excavation.

It is estimated that the entire work from Philadelphia to Staten Island would cost $12,500,000.

This would constitute the most important link in the interior waterway of the Atlantic Coast, connecting the most populous and most valuable centres commercially and strategically. Its advantages to the entire country can hardly be overestimated as a factor in preserving peace and promoting prosperity.

EXPERIMENTS MADE TO ASCERTAIN THE SPECIFIC VOLUMES OF THE SATURATED VAPORS OF WATER, BISULPHIDE OF CARBON, AND ETHER, TOGETHER WITH VARIOUS MEASURES CONCERNING THE LATTER; ALSO THE DETERMINATION FROM THE EXPERIMENTAL DATA THUS OBTAINED OF THE MECHANICAL EQUIVALENT OF HEAT.

By A. Perot.

Translated by Chief Engineer Isherwood, U. S. Navy.

[*A thesis presented to the Faculty of Sciences of Paris.*]

The specific volume of saturated vapors, or what inversely amounts to the same, namely, the mass of their cubic centimetre, is of the greatest theoretical interest, because it is a factor in numerous thermodynamical equations from which the mechanical equivalent of heat may be calculated.

The experimental researches for determining this quantity are very few, and they are in principle similar to Gay-Lussac's method for measuring the densities of dry vapors. I shall pass them in rapid review.

The first experiments were those made in 1860, by Messrs. Fairbairn and Tate,* on the vapor of water. Their process consisted in introducing a known weight of water into a vacuous vessel of known capacity, and ascertaining the temperature at which the whole of the water was transformed into saturated vapor. The water, contained in a completely filled and sealed phial, was introduced into a balloon that communicated by means of a manometrical tube with a surrounding inclosed space in which the saturated vapor was produced in presence of an excess of water. This inclosed space surrounded the balloon in such a manner that the temperature in the space and in the balloon was exactly the same. The rise of the temperature broke the phial, but as long as the whole of the water in the inner balloon was not vaporized, there was no difference between the heights of the two columns of mercury of the manometer; as soon, however, as the vaporization was complete—the temperature continuing to increase—the mercury began to rise in the manometrical branch communicating with the balloon, and at that instant the temperature of the thermometer, and the volume occupied by the vapor, were noted, which latter is possible when the manometrical tube has been gauged. The levels were observed with a magnifying glass, and the thermometer—directly immersed in the vapor—was corrected for the influence of the pressure upon it. Knowing, then, the volume occupied by the vapor, the weight of water vaporized, and the temperature, the specific weight of the saturated vapor can be easily calculated. The experiments show that this weight is always greater than that which is due to the laws of Mariotte and Gay-Lussac.

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* *Philosophical Trans.*, 1860, and *Phil. Magazine*, vol xxi, 4th Series, p. 231. 1861.

This elegant and simple method of Messrs. Fairbairn and Tate also allows the dilatation of superheated steam to be determined, for the pressure of the vapor is known from the difference between the levels of the mercury in the two legs of the manometrical tube, while its volume can be ascertained by previously graduating that tube in divisions of equal capacity,

The arrangement of the apparatus is adapted for measuring specific volumes, because the errors which may be made in determining them are of the same order as those which may be made in ascertaining the temperature. For example, if it be supposed that the manometrical tube had one square centimetre of section, and that $2x$ denotes the difference between the level of the mercury in the two legs of the manometer produced by $0^{\circ}{\cdot}1$ increase of temperature above the temperature of exact saturation, x could be calculated according to the following equation given by the experimenters.

$$H'V' = HV\left(1 + \frac{0.1}{r}\right)$$

the pressure H and the volume V being relative to the exactly saturated vapor, and H' and V' to the condition produced by the 0°·1 elevation of temperature; knowing also that

$$H' = H_{t+0{\cdot}1} - 2\,x$$

that $V' = V - x$, and substituting for r the value given by Messrs. Fairbairn and Tate. When $t = 70°{\cdot}75$ for example, $r = 83{\cdot}33$, $H_{70{\cdot}75} = 24{\cdot}1$ centimetres, $H_{70{\cdot}85} = 24{\cdot}2$ centimetres, there would be approximately

$$x = 0{\cdot}036 \text{ centimetre},$$

so that the difference of level $2\,x$ between the two legs of the manometer would be about 0·07 centimetre, a quantity appreciable with certainty; the error to be feared as regards the volume would then not exceed the diminution of volume resulting from an increase of 0°·1 of temperature. There are, it is true, difficulties as regards accurate reading, the light having to traverse the thickness of the glass before reaching the manometrical tube and the thermometers, consequently, the accuracy above indicated should be regarded as a maximum.

In 1868, Herwig* undertook to measure anew the variations of the product PV of the pressure of a given mass of vapor by its volume, when that vapor passes from the condition of saturation to the condition to which the laws of Mariotte and Gay-Lussac are applicable. He varied the pressure of a given mass of vapor at constant temperature, and measured the volumes successively occupied. The results that he obtained relatively to the variation of the product PV, in operating on alcohol, chloroform, and the bisulphide of carbon, are interesting, but his method considered as one for the determination of specific volumes, is open to some objections. In these experiments he failed to measure with precision, at a constant temperature, the volume occupied by the mass of the substance experimented with when the saturation was exact; that is to say, at the moment when in augmenting the volume progressively, the pressure commenced to diminish: this diminution of pressure was the sole criterion by which he could judge when the saturation was exact. In estimating the value of this method, a clear understanding must be had as to whether that indication was sufficiently sensitive, and, if not, whether, for appreciable variations of pressure, variations of volume are negligable; now it can be easily comprehended that such is not the fact.

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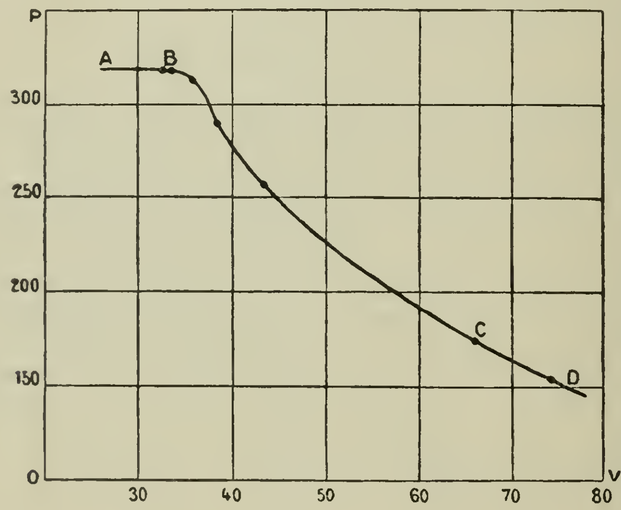
* Herwig, *Pogg. Ann.*, vol. cxxxvii, p. 19. 1869.

Fig. 1.



Taking p and v as variables, representatives of the condition of the substance, let there be constructed, point by point, with the numbers given by Herwig, the corresponding isotherm for the vapor of alcohol at, for example, $t = 57^\circ{\cdot}8$:

	cm	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*	*cm.*
p, ...	31 581	31·580	31·163	28·903	25·713	17·306	15·400
v, ...	33·0	33·3	36·0	38·7	43·7	65·7	74·0

Exact saturation occurs, according to Herwig, when $p = 31{\cdot}580$, and $v = 33{\cdot}3$. The trace (*Fig. 1*) is composed of a *rectilineal* part *AB* parallel to the axis *OV*, corresponding to the saturated condition, and of a *hyperbolic* part, corresponding to the condition of a vapor following the laws of Mariotte and Gay-Lussac, united by a *connecting* curve at B to the rectilineal part in such manner that near B the variations of pressure corresponding to very large variations of volume are very small, in which case the value of V' must be extremely uncertain.

Herwig was led by the lack of sensitiveness of his method to invent an empirical law connecting the product PV of a vapor following the laws of Mariotte and Gay-Lussac, with the product pv of saturated vapor; he put

$$PV = pv\, C \sqrt{T},$$

C being a constant and T the absolute temperature, then verifying the equation from such of his experimental groups whose values of p, v and T he considered to have been determined with the most precision, he obtained for it a value of C and corrected the results of his other experiments by means of that formula; in other words, he determined empirically the specific volume. This had the effect of replacing the trace representing the states of exact saturation, by the following one:

$$p\,v = \frac{PV}{C\sqrt{T}} = \frac{1}{C} P_0\, V_0 \sqrt{T} = C_1 \sqrt{T};$$

which can only be applied within very restricted limits of temperature.

In 1880, Messrs. Wüllner and Grotian* repeated these measurements with an apparatus which may be considered as a combination of those of Herwig and of Messrs. Fairbairn and Tate. The space where they produced and investigated the vapor was within an assemblage of three inverted balloons whose necks, graduated in parts of equal length and equal volume, communicated with a receptacle filled with mercury under a known pressure; a fourth balloon, under the same conditions, contained the vapor in a constant state of saturation owing to the presence of an excess of liquid; it served as a bench-mark in the experiments and corresponded to the space which surrounded the balloon in the apparatus of Messrs. Fairbairn and Tate. Finally, the four balloons were immersed in a liquid bath, kept properly agitated, whose temperature was exactly measured. The volumes of the first three balloons were in the ratio of 1, 2 and 4. The weight of liquid introduced into them was in the same proportion as the volumes; the liquefaction of the vapor would be effected at the same moment in the three spaces. The temperature was raised, and the pressure was so regulated as to cause dry vapor in the three balloons: the temperature being maintained constant, the vapor was very slowly compressed, and the instant that fog or wet steam appeared on the sides was considered to be the instant of exact saturation. The observations made on the three balloons were always concordant, but the liquefaction was produced by a pressure a little less than the maximum pressure of the saturated vapor observed in the fourth balloon.

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* Wüllner and Grotian, *Wiedemann's Annalen*, vol. xi, p. 545 (1880), and Wüllner, *Lehrbuch der Experimental-Physik*, vol. iii, pp. 705 and 758 (1885).

In the first place, as Mr. Wüllner remarks, if the apparent irregularity of the condensation then found was due to the action of the sides, its effect ought to vary with the proportion of the surface of the balloon to the volume of the same; the greater that proportion the greater should be the condensation of the vapor on the sides, and *vice versa*. In operating with balloons of unequal capacity, there should be found for the specific weight of the vapor, numbers varying in the same direction as the capacities, or this cause amounts to nothing.

The influence of the sides, if it exist, would be masked by much more important phenomena. It seems that this apparent irregularity—(and a considerable one, too, since the ratio of the observed pressures to the pressures corresponding to the saturated vapor, has, for water, the sensibly constant value of 0·01)—can be explained in the following manner:

In considering the assemblage formed by the isotherms corresponding to temperatures below and above the critical point of a substance, Mr. James Thomson* was led to think that the passage from the gaseous state to the liquid state could be insensibly made, the substance remaining homogeneous. The isotherms representing such a change of state have no horizontal part, but are continuous and have a form

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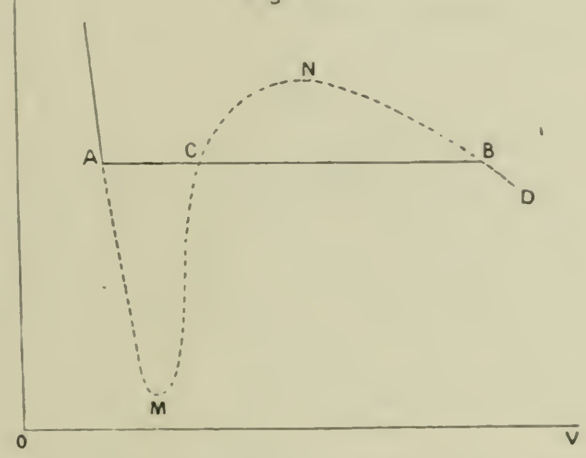
* J. Thomson, *Proceedings of Royal Society of London*, November, 1871.

Fig. 2.



like *AMND* (*Fig. 2*). Several scientists, taking this conception as a basis, have devised different formulæ to represent the law connecting the pressure with the volume. Among them, Mr. Clausius* has proposed the following:

$$p = \frac{RT}{V + \alpha} + \frac{F(T)}{(V + \beta)^2}$$

R being the constant of the law of Mariotte, T the absolute temperature, α and β two specific constants of the substance.

The numbers calculated by Mr. Sarrau† resulting from the application of this formula to carbonic acid, are in very satisfactory accord with those obtained by Messrs Cailletet and Mathias‡ in their recent experiments on liquefied gases.

If, in this formula, T be supposed constant, the isotherm represented will have, in fact, the form shown in *Fig. 2*. Mr. Clausius has elsewhere made it evident that the horizontal part found in constructing the isotherm with the experimental data, should be so placed that the areas *AMC* and *CNB* would be equal.

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* Clausius, *Wiedemann's Annalen*, vol. ix, p. 127, 1879.

† Sarrau, *Comptes Rendus*, vol. ci, pp. 941, 994 and 1145.

‡ Cailletet and Mathias, *Journal de Physique*, 2d series, vol. v, p. 549, 1886.

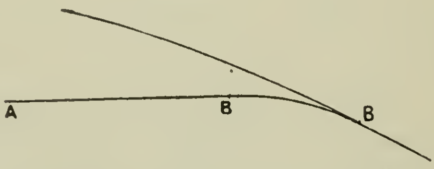
What is the nature of the point B considered as appertaining to the trace $EACBD$? Is it a *curved connecting point*, or an *angular point?* If it were an angular point, the volume augmenting in departing from a point in the straight line AB, the variable B would enter abruptly into the expression of the pressure, which seems could not be the case as

$$\frac{dp}{dt}$$

would then become a discontinuous function.

With this difficulty in the case, and having regard to the isotherm constructed with Herwig's numbers, represented in *Fig. 1*, there appears more probability that the straight line AB connects with Mr. J. Thomson's curve in the manner shown in *Fig. 3*, and there follows that the representative point of the state of the substance at the instant when there was no more liquid, and when the vapor was still saturated, is not on the parallel to the axis of the volumes, but below at B', so that *the condensation will commence at a pressure less than the maximum pressure of the vapor.* Thus what Messrs. Wüllner and Grotian have measured is the specific volume of the vapor in a particular state, a volume which is not the inverse of the specific weight of saturated vapor in presence of an excess of liquid.

Fig. 3



Messrs. Fairbairn and Tate, as well as Herwig, measured the specific volume when there was not enough liquid to produce the maximum tension; in other words, if Messrs. Wüllner and Grotian sought the abscissa of the point B', Fairbairn and Tate, and Herwig, determined that of the point B.

Referring, further, to the measures of the specific volume of the saturated vapor of chlorhydric gas, made by Mr. Ansdell,* and to the determinations effected by Messrs.

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* Ansdell, *Proceedings Royal Society*, vol. xxx, p. 117, 1879.

Cailletet and Mathias* on liquefied gases, these measures being made according to the same principle as those of the experiments of Herwig: there was determined the mass of a given volume of gas under known conditions of temperature and pressure. This mass, first reduced to the liquid state, is vaporized and the volume measured at the instant of exact saturation as near as can be detected, either as in the case of Mr. Ansdell, by observing the movement of a manometer, or, as in the case of Messrs. Cailletet and Mathias, by watching the moment when the last drop of the liquid disappeared. These measures are very interesting, not only because they are the first made on the respective substances, but also because they have a degree of precision very difficult to attain when such high pressures are employed; the methods, however, are not sufficiently exact for the object I have in view.

From the preceding exposition there can be drawn the following conclusion: All the measures of the specific volume of saturated vapors, that have been made, or attempted, by seeking to determine the volume at the state of exact saturation, necessarily include a source of error, small, it is true, but inherent in the methods adopted. To obtain the precise determination of the weight of the cubic centimetre of saturated vapors, it is necessary to operate in the presence of an excess of the liquid. This is what I have endeavored to do, and the following experiments, which I am about to relate, were made under that condition.

This memoir is divided into two parts: In the first, I describe in detail the processes I have employed for measuring the specific volume of saturated vapors; in the second, I apply the data thus found to the calculation of the mechanical equivalent of heat; it contains, further, the determination with a known degree of approximation, of the numerical values of a certain number of important factors employed in this calculation.

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* Cailletet and Mathias, *Journal de Physique, loc. cit.*, 2d series, vol. v, p. 549, 1886.

But before proceeding, I must be allowed here to express to Messrs. Bichat and Blondlot the profound and respectful gratitude to which they are entitled from me. They have freely placed at my disposal the resources of their laboratory, and if I have profited during several years from the wise counsel and high experience of Mr. Bichat, I am happy to say that Mr. Blondlot has likewise guided and supported me in this my first work.

CHAPTER I.

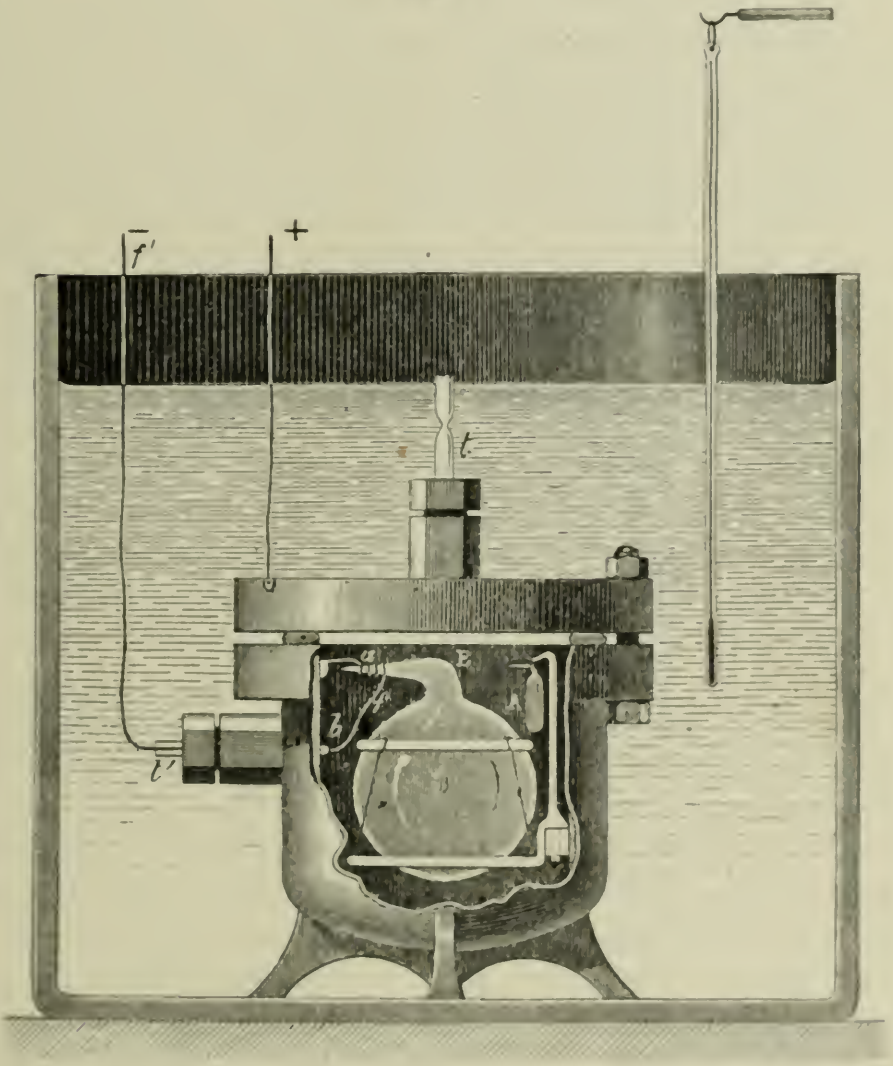
Measure of the Specific Volume of Saturated Vapors.

Two methods have been employed for measuring the specific volume of saturated vapors, but in both will be found realized the condition of which I have previously shown the necessity. The weight of the cubic centimetre of vapor, and consequently its inverse, the specific volume, is determined by isolating in an atmosphere of saturated vapor a certain volume, and measuring the mass of that volume.

First Method.—Imagine in a vacuous space *E*, a balloon, equally void, in communication with it, but which can be isolated at a given instant, and that there can be produced in this space an atmosphere of the saturated vapor of a liquid of known temperature. The balloon will fill with this vapor, and if it be then closed the mass of the substance within it can be ascertained by weighing, and from this mass can be deduced the weight of a cubic centimetre of the vapor, and also its inverse, the specific volume.

This method of experimenting has been realized in the following manner: the inclosed space where the saturated vapor is generated is the interior *E* of a bronze boiler (*Fig. 4*), which can be closed by a cover bolted on, and in which a vacuum can be formed by means of a glass tube *t*, passing out through a packed stuffing box. After this boiler has been several times washed out by the liquid which is to be the subject of the experiment, in order to eliminate all trace of any other substance, there is placed on a support in it a balloon, tared, full of dry air, and similar to those employed for determining the density of vapors according to the process of Dumas; the method employed for drying the balloon is the one used by Regnault: produce a vacuum in the interior and allow the air to enter about thirty times. Around the extreme end of the neck of the balloon, which has been drawn out to a fine point, there is coiled a platinum wire *f*, one of whose ends is fastened to the side of the boiler at *a*; the other end *b* is secured to another platinum wire *f'* which passes through the side of the boiler in a glass tube *t'*, and is thus isolated from the boiler. At the side of the balloon there is placed in the interior of the boiler a phial *A* full of the liquid to be operated on. To

Fig. 4.



secure a hermetical joint without the use of any fatty substance, there is placed between the boiler and the cover a circle of lead wire which is flattened by screwing up the bolts. The two stuffing boxes for passing out, the one, the isolated platinum wire; the other, the glass tube *t*, are packed either with rings of cork or with a mixture of flax and talc. The interior of the boiler is dried by several times causing a vacuum in it and allowing dry air to enter, then, after the last time, the air is extracted as completely as possible, first, by a Carré machine, and then by a mercurial pneumatic machine. The rarefaction in the last experiments made on ether at low temperatures, was so complete that the difference between the levels of the two columns of the manometer was not more than about half a millimetre. The glass tube *t*, which established the communication between the machine and the boiler, is now hermetically sealed, and the latter is placed, according to the case, into a bath of olive oil, or into a water bath, previously heated to about the desired temperature. The bath is kept in continuous agitation by a mechanically operated sucking and forcing pump, which draws the oil or water from the bottom of the bath and returns it above the top of the boiler.

The dilatation of the liquid in the phial breaks the latter and furnishes within the apparatus the saturated vapor which enters and fills the balloon. The duration of the heating was always more than three hours, and in one experiment it was nearly a day and a half. A regulator controlling the delivery of the gas, prevented too great variations in the temperature. There was used in these experiments a glycerine regulator, the advantage of which consisted in combining independence of the atmospheric pressure with sufficient sensitiveness; at 150° the variations, very rapid, did not exceed $\frac{1}{4}$°. At the end of an experiment I was particular to maintain for twenty or thirty minutes the temperature constant, at least, to about $\frac{1}{10}$°, with increased care for preventing cooling effects due to exterior causes. For closing the balloon, there was passed through the platinum wire *f* the current from a small Gramme machine, one pole of which was attached to the side of the boiler and the other to the wire *f′*. The platinum wire *f* became highly heated, melted the glass, and the point was hermetically sealed the same as if done by a blow-pipe.

The boiler is lifted from the bath and allowed to cool, then the cover is removed and the balloon, in which a part of the vapor has been condensed, is taken out. The operation is finished by measuring the density of the dry vapor according to Dumas' process. The gauging is made either with water, or, preferably, with mercury; the air which remains is ascertained, and its volume should never exceed four cubic centimetres, 200 cubic centimetres being the mean capacity of the balloon.

The following are the results I have obtained in operating at different temperatures on water, on the bisulphide of carbon, and on ether:

Name of the Liquid.	*Temperature in Degrees.*	*Volume of the Balloon at 0° in Cubic Centimetres.*	*Specific Volume of the Vapor in Cubic Centimetres.*
Water, ...	68·20	243·0	5747
	88·60	188·1	2531
	98·10	222·3	1782
	99·60	219.0	1657
	101·50	196·92	1583
	124·10	169·92	766
Bisulphide of carbon, .	84·60	171·19	116·3
Ether, ...	28·40	174·57	426·2
	30·00	177·98	400·0
	31·70	182·42	375·1
	31·90	182·64	373·0
	57·90	208·40	168·0
	85·50	215·50	77·77
	110·50	150·35	43·94

I will here give some information relative to the practical particulars of the experiments.

I have not been able to experiment on water much above 100°, because the surface of the glass becomes greatly altered above this temperature by the saturated vapor; thus, with 140°, at the end of three hours' heating, the interior of the balloon had been so attacked that a white and opaque skin of silica would scale off like a thick pellicle of retractile collodion. The experiment in the above table, made at 124°·10, should, for this reason, be considered doubtful, At 101°·5 I have not observed any attack of the kind. The experiment made with that temperature lasted thirty-two hours, and the glass, when the balloon was lifted out of the boiler, was as transparent as when the balloon was placed in it. This experiment, made under eminently favorable conditions for such an attack on the glass, shows that below 100° in the other experiments, which lasted at the longest five hours, the attack was absolutely nothing.

When the bisulphide of carbon was experimented with, the sealing of the balloon was attended by some difficulties. This substance is decomposed at a red heat, and the sulphur combining with the platinum forms a fusible sulphuret of platinum, the wire breaks, and the current no longer passing, the balloon frequently remains open.

With ether, the current should be sent rapidly; the point of the neck should be of very thin glass, for a deposit of carbon, due to the decomposition of the ether at a high temperature, is quickly produced on the wire, which deposit hindering the contact of the glass with the metal prevents their being soldered together. If the point be thick, the balloon does not become closed, while, if the glass be thin, it is melted before the carbon deposit can acquire any notable thickness. This partial decomposition of the vapor cannot in the least falsify the results of the experiments, for it takes place outside of the balloon, into which the gas cannot penetrate during the very short time of the passage of the current. In the first experiments made on ether at low temperatures, the dilatation of the liquid was not sufficient to break the phial containing it, in which case I opened the phial by a process the inverse of that by which I had closed the balloon, namely, by means of a current penetrating into the apparatus by a second isolated wire, I melted the point of the phial, and there being a vacuum in the boiler, a hole was produced by the pressure of the vapor through which the latter escaped.

[*To be continued.*]

FOURTH CENTENNIAL OF THE DISCOVERY OF AMERICA.

[*Official Announcement of the Historical American Exhibition of Madrid.*]

One of the acts with which the Spanish Government has decided to commemorate the Fourth Centennial of the Discovery of America, as ordered by the Royal Decree of ninth of February last, is the establishment at Madrid of an exhibition that is to comprise every kind of American objects, giving at the same time an idea of the civilizations of the New World, anterior to and coëval with the epoch of the discovery and European conquests.

This purpose being known, it seems unnecessary to overrate the importance of this Exposition. The mere announcement of it suffices to enable one to appreciate the great elements that science will find for its progress and the numerous data that arts will collect to complete the knowledge of those mighty races about which so much remains to be known and investigated.

Besides this interesting aspect, the Exhibition symbolizes the homage paid by the present generation to the gallant and fearless navigator, who, with unshaken faith, opened to the Old World's civilization, the vast horizons of an unknown continent, the influence of which, in the course of time, has increased the wealth and prosperity of every country of the earth.

With such patriotic incitements, the committee has not the slightest doubt of your valuable assistance by sending to the Historical-American Exhibition any objects in your possession of American origin or referring to the conquest, anterior to the middle of the eighteenth century, of the following classification :

PREHISTORIC AMERICA.

Plans, models, reproductions or drawings of ancient American caverns and everything showing any trace of their having been used as human dwellings.

Plans, models, representations or drawings, etc., of American menhirs, dolmens, tumuli and other megalithic monuments, with specification, if possible, of the local names by which they are known in the country.

Models, drawings, representations, etc., of the remains of lacustrine dwellings and objects coming from that period. Every kind of objects found inside and near the prehistoric monuments, or graphic designs of the same.

Stone arms and instruments from the paleolithic and neolithic periods; articles made of horn and animal bones. Pottery, ornaments, utensils made of bones, ivory, wood, stone and of any other materials; stone-hammers and mortars. Fossils, or animal bones serving to prove the archæological discoveries of those ancient periods.

Arms, instruments, utensils, ornaments and other implements of the copper and bronze ages.

HISTORIC PERIOD.

Models or representations of ancient American buildings, remains of chapiters, cornices, etc. Polychromatic architecture. Plans, models or drawings of restored monuments.

Statues, fragments of them, busts, bas-reliefs, etc. Pictorial art—painted architectural fragments and paintings on every sort of materials. Engravings and etchings, antique wood carvings.

INDIAN INDUSTRIAL ARTS, ETC.

Clothing and adornment of aboriginal uncivilized and but partly civilized Indians. Implements of war, offensive and defensive, of wood, copper, bronze and iron.

Gold, silver, bone and ivory jewels; necklaces, ear-rings, bracelets, etc. Pottery, household utensils and furniture. Tissues and textiles from which they are made. Apparatus for manufacturing purposes. Articles used in transportation by water and land.

Documents written in their native tongue. Pictures, photographs of Indians and effigies of the same with their wearing apparel, weapons, etc. Models of Indian dwellings. Indian crania.

CARTOGRAPHY, NAUTICAL INSTRUMENTS, ETC.

Maps, plans, charts, drawings and all that relates to the ancient cartography. Models of vessels anterior to the voyage of Columbus. Carabelas, portions of the same, or of their rigging. Models or drawings thereof.

Astrolabes and nautical instruments, marine charts and maps used at the period of the discovery of America. Objects of personal use of Columbus ; pictures of the same. American architectural monuments.

FINE ARTS, ETC.

Ancient architectural monuments, sculpture, paintings, engravings, industrial and artistic works following the discovery, American coins, literary and scientific publications, manuscripts, charts and plans from the discovery to the middle of the eighteenth century.

As you will naturally wish to know the conditions and circumstances attending the celebration of the said concourse, those more important for exhibitors are inserted here below, as consigned in the general regulations approved by the Managing Committee of the Exhibition, viz :

(1) The Exhibition will take place in Madrid, in the palace destined to the Library and National Museum, which will be inaugurated on this occasion, as well as in the Park of Madrid. (Art. 2, of the Regulations.)

(2) The concourse will be opened to the public on September 12, 1892, closing on December 31st, following. (Art. 2.)

(3) The objects destined to the concourse will be delivered to the Spanish Committee of this capital, whose address is given below. This committee will forward, gratis to all applicants, the regulations, instructions and particulars, as also schedules of inscription to be filed by those wishing to be considered exhibitors, and will, in due time, hand over receipts for all objects delivered by the latter.

These objects must be presented in good condition, in cases, and packed with the care required for conveyance.

At the request of applicants and in their presence, the packages delivered by them may be marked and sealed.

Schedules and labels will be furnished to exhibitors wishing to consign their remittances to Madrid. (Arts. 18, 22 and 24.)

(4) Once the packages in the hands of the committee, all expenses of conveyance of same to Madrid and back will be paid by the Managing Committee, the exhibitors thereby incurring no further expense. (Art. 26.)

(5) In the same way in the building and grounds of the Park, the plans of which can be seen at the offices of this committee, the necessary space will be allotted gratuitously to exhibitors to install in an ample and proper manner the objects they present. The cost of the general installation will be at the expense of the Managing Committee. The exhibitor desirous of an accommodation special or distinct from the general one, may have it at his expense, provided the design he must submit to the general delegation be previously approved of. (Art. 30.)

(6) Packing materials and empty cases will be kept in a fit and safe place by the delegation, no charge being made to exhibitors for this service. (Art. 29.)

(7) Exhibited objects may not be withdrawn before the official closing of the concourse, except in case of special permission from the general delegate.

(8) All the installations of the Exhibition must be finished on the 31st of August, 1892. (Art. 32.)

(9) Exhibitors desiring to sell their exhibited objects will mark the price of same on the schedules and labels for the information of the public, as well as for the easier judgment of the members of the jury. (Art. 34.)

(10) Immediately after the closing of the Exhibition, the packing and return of objects exhibited will take place.

The cases or parcels that may not have been delivered in Madrid, will be sent by the general delegation to the committee through which they were received. In their turn the said committee will hand them over to the exhibitors, taking back, at the same time, the receipts formerly given to the interested parties.

In case of loss of said receipts, they may be substituted by documents proving the property of the objects. (Art. 38.)

(11) To each exhibitor, or in his absence to the representatives, will be given a free pass to the Exhibition. (Art. 44.)

(12) In view of the lists that the exhibitors will hand to the general delegation, this latter will issue likewise, gratis, the necessary tickets for service of care-takers, attendants and workmen required for the installation. (Art. 47.)

(13) All objects from foreign countries to be transmitted to the Exhibition will be considered as a deposit and consequently free from any custom house or toll duties, on condition that at the closing of the Exhibition said objects be returned abroad.

Orders will be transmitted for the land and maritime custom houses to mark and forward all consignments immediately to Madrid. (Art. 52.)

(14) The return abroad of objects exhibited will take place during the term of two months, counting from the day on which the closing of the Exhibition has been declared. (Art. 55.)

(15) The delegation will publish a general catalogue of all the objects that appear in the Exposition, giving the name and address of each exhibitor; and the class, nature and a brief description of everything exhibited. (Art. 56.)

(16) Besides the general service for custody and safety to be organized by the general delegation, the commissaries or delegates of foreign nations, as well as any exhibitor wishing to form an association, may at their own expense appoint special guardians for the security of their respective departments who shall submit to the rules of organization and service determined by the general delegation, and shall wear by previous authorization, the uniform and distinctive marks agreed upon. (Art. 78.)

(17) For the examination and qualification of the merit of the objects exhibited, an international jury will be appointed, and the number of its proprietary substitute

members will be determined in proportion to the number of exhibitors and the importance of the objects exhibited. (Art. 60.)

(18) The prizes to be granted will consist of diplomas of the following categories: .

First Prize of Honor,
Gold Medal,
Silver Medal,
Brass Medal,
Honorable Mention.

The diplomas will be accompanied by a medal commemorative of the Exposition, the same for every kind of prize. (Art. 66.)

(19) It will be understood that all exhibitors from the mere fact of appearing at the Exhibition, accept the conditions contained in the General Regulations and any others that may be in future dictated in the matter. Having made known the substance of the contents of the General Regulations of the Historical-American Exhibition, a copy of which will be forwarded to you, should you wish to be an exhibitor, the commission reiterates the request that you will honor the said Exhibition with your presence, and it will have the greatest pleasure in giving you all the information and particulars you may consider necessary to induce you to accept the present invitation which the Managing Committee of Madrid now extends to you through me.

I avail myself of this opportunity to offer you my respects, and beg to remain,

Your obedient servant,
THE VICE-PRESIDENT OF THE COMMISSION,
A. G. DEL CAMPILLO,
Secretary of the Spanish Legation.

WASHINGTON, D. C., December 1, 1891.

EDITORIAL.

We commend not only to our readers but to our legislators, whether readers or not, the able paper of Prof. Haupt in this number. The two subjects which seem to remain a mystery in spite of all efforts to elucidate them are: (1) the decline of the merchant marine of the United States, and (2) the decline of Philadelphia as a shipping and commercial centre. Prof. Haupt's article throws much light on the latter of these questions.

* * *

Attention is called to the circular of the commission for procuring a suitable representation of American exhibits at the Spanish Exposition next year in commemoration of the fourth centennial of the discovery of this continent by Europeans. The display in Madrid will not only not prejudice the success of the larger display in this country, but in fact the more perfect it is, the greater will be the gain to our own fair of the Columbian quadri-centennial in Chicago. As United States citizens also we will accept with pleasure this opportunity of showing good-will and courtesy to the mother of most American nations, the grand old Kingdom of Spain. We have had more than enough lately of strained relations and hard feelings toward other Latin members of the world's family, and it is a relief to be able to prove that our desire is to maintain cordial feelings of mutual respect and esteem with all.

* * *

The management of the weekly illustrated review, *L'Elettricita*, which has appeared for ten years in Milan, has established an international competition for the new form of electric battery which shall be most practical, simple and adaptable to industrial uses. The competition will remain open from January 1st to August 31, 1892. A prize of 2,000 francs will be awarded to the inventor who wins in the competition. The jury will be composed of well-known and competent persons.

The competitors must observe certain regulations of which they may be apprised by addressing the said *Revue*. Address, *L'Elettricita*, via Meravigli 2, Milan, Italy. F.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, December 15, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 15, 1891.

Dr. W. H. WAHL, President, in the chair.

Present, ten members and one visitor.

Dr. Jayne moved that the by-laws be suspended and the regular order of business be done away with. Carried.

The resignations of Messrs. Stevens and Gudeman were accepted by the Section.

A motion renewing the subscriptions to the various periodicals, and authorizing the treasurer to pay for the same, was carried.

The paper of the evening was by Prof. Jos. W. Richards, on "The Specific Heat of Aluminum."

After a *résumé* of the work already done in that direction, Prof. Richards brought forward the results recently obtained by him. The paper was referred for publication.

The meeting then adjourned.

LEE K. FRANKEL, *Secretary pro tem.*

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, December 1, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 1, 1891.

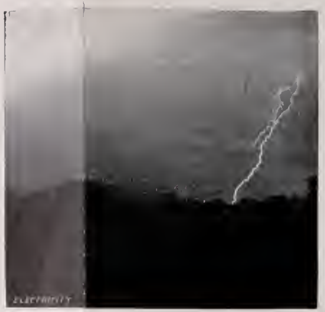
Prof. EDWIN J. HOUSTON, President, in the chair.

Present, thirty members and visitors.

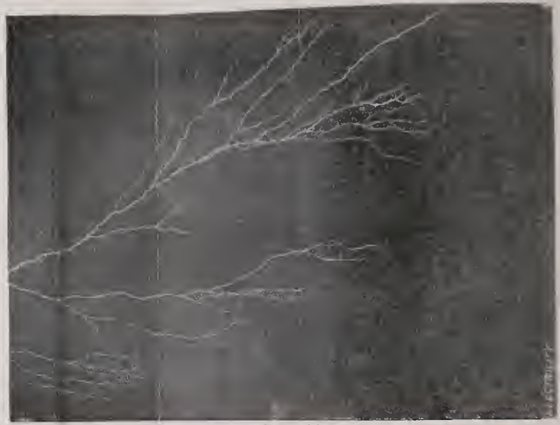
The minutes of the previous meeting were read and approved.

Three nominations to membership were referred to the Committee on Admissions. The committee reported four elections since last meeting.

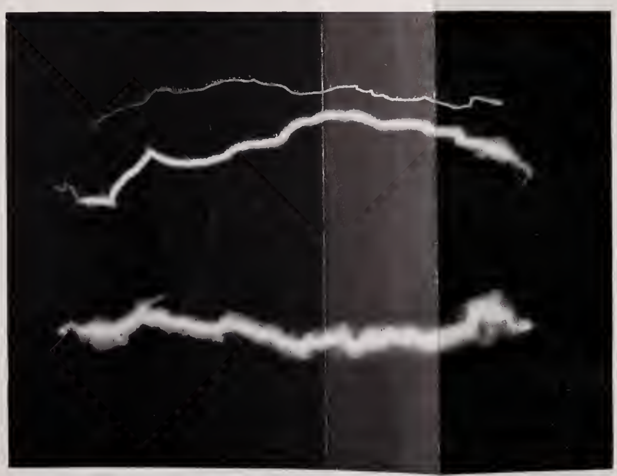
(1) Sketch of conventional “artist's” lightning.



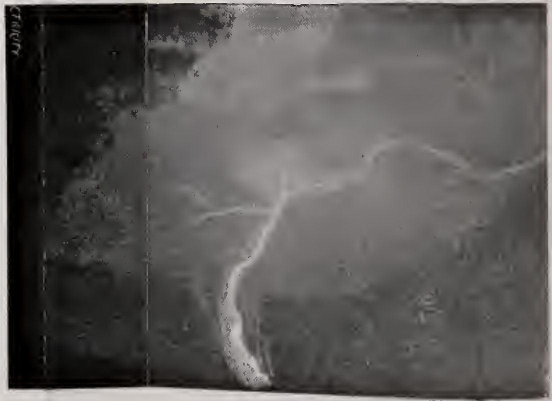
(3) Wavy vertical discharge with branches.



(4) “Tree” form of lightning.

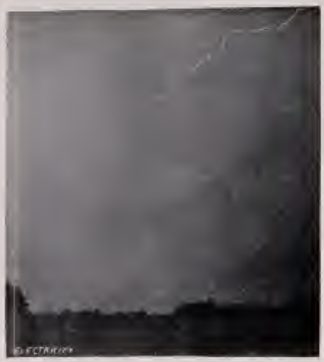


(2) Artificial lightning. (Holtz machine sparks.)

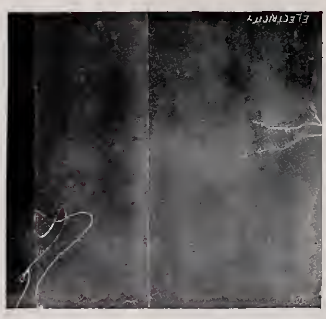


(5) Vertical stratified discharge.

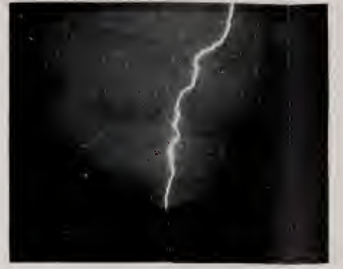
VARIOUS FORMS OF LIGHTNING DISCHARGE. (Reproduced from photographs by W. N. Jennings.)



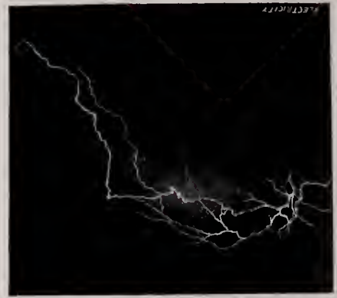
(6) Divided discharge.



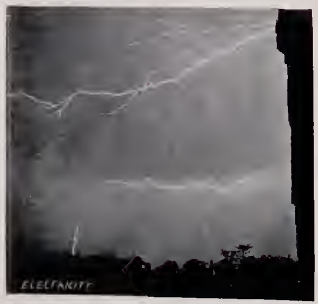
(8) Loop form of lightning.



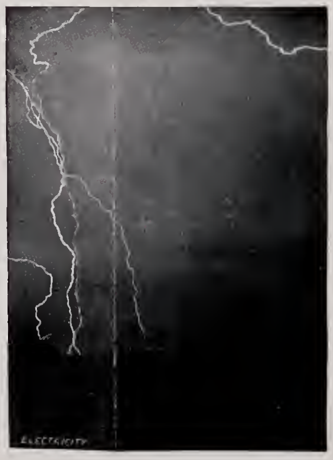
(11) Vertical discharge with dark branches.



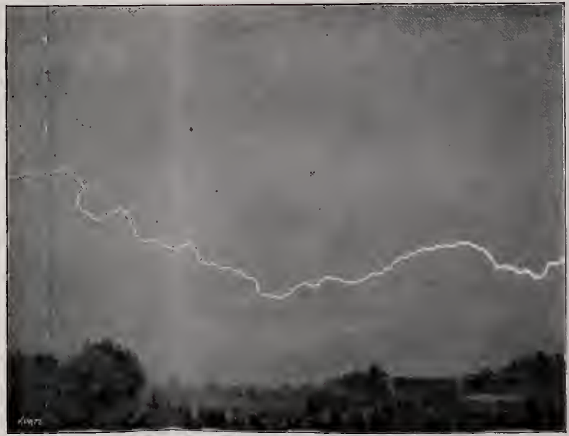
(12) Parallel discharge converging into one main stem.



(7) Double horizontal discharge. (Simultaneous.)



(9) Meandering discharge.



(10) Horizontal discharge.

VARIOUS FORMS OF LIGHTNING DISCHARGES. (Reproduced from photographs by W. N. Jennings.)

The Secretary presented his annual report, which showed an increase in the membership from sixteen at the organization January 17, 1891, to sixty-four at present, with an average attendance of twenty-six at the ten meetings held during the year.

The Treasurer presented his annual report, and it was referred to the Committee of Auditors.

The following were elected officers for 1892:

President—Prof. Edwin J. Houston.

-Presidents—Messrs. C. W. Pike and Carl Hering.

Secretary and Treasurer—Prof. L. F. Rondinella.

Conservator—Dr. Wm. H. Wahl.

Mr. H. W. Bartol presented a communication on the "Electric Railway of Buda-Pesth," illustrated. Referred for publication.

Mr. Carl Hering described some details of the "Lauffen-Frankfort Alternating Current Transmission," with illustrations.

Mr. Wm. S. Aldrich read a paper on "Electro-Magnetic Machinery," which was profusely illustrated, and is to be continued.

The Treasurer presented bills for printing, etc., which were approved and ordered paid.

Adjourned. L. F. RONDINELLA, *Secretary.*

JOVE'S AUTOGRAPH.

By W. N. JENNINGS.

[*Read at the stated meeting held November 3, 1891.*]

To watch the play of electric fire and listen to the deep echo of its voice has always been to me a most fascinating pastime. Many years ago I noted a great difference between the actual appearance of lightning itself and that depicted by artists such as Doré: in the sky, a graceful, waving ribbon of light, and on canvas, an awkward, angular, zig-zag line. Thinking, perhaps, my eye-sight was defective, it occurred to me to see if the modern extremely sensitive photographic plate could catch and record the true form of an electric discharge, and thus definitely decide the question as to the zigzag or wavy line. The work was commenced, but not until September, 1882, was I enabled to induce Jove to write his autograph; a little *wavy line* about a half an inch long; thus encouraged the task was taken up with renewed interest, which has never flagged since that time, and now it gives me great pleasure to bring before the Electrical

Section of the Institute, a number of photographs representing various types of lightning, the result of nine years' work: (See *Frontispiece.*)

(1) A sketch of the conventional form of lightning as given by artists, and may be termed a "Doré discharge."
(2) Artificial lightning, or Holtz machine spark, the increased thickness being due to the addition of condensers.
(3) Sinuous vertical discharge, with branches, taken August 1, 1885.
(4) "Tree" form of lightning, caught June 1, 1887.
(5) Vertical discharge showing stratified lines near its lower extremity, taken May 29, 1888.
(6) Divided discharge, caught August, 1886.
(7) Double horizontal discharge (both occurring at same time), taken August, 1890.
(8) Loop form of discharge, having a spiral line running its entire length, taken June 10, 1890.
(9) Meandering discharge.
(10) Horizontal discharge, taken June 11, 1890.
(11) Vertical discharge, taken ten minutes later than 10.
(12) Parallel discharge: Two almost parallel lines converging into one main stem, taken April 17, 1891.

It will be noted that in all these photographs the wavy character is maintained, and also that the line grows thicker as the discharge progresses.*

There has been a question raised as to whether (10) really represented a lightning discharge or was merely a defect or scratch upon the surface of the photographic plate. It has been my practice to note in my diary particulars of the storm and a pen-and-ink sketch of the forms of lightning photographed as they appeared to the eye, this being done while the impression was still strongly written upon the mind. The following note appears in reference to (10), and the preconceived sketch, made before the plate was developed, has the same general outline as the photograph:

"June 11, 1890. Most remarkable storm occurred last night. At 10 o'clock took my little kodak and went off into the country. Got some beautiful low horizon effects. At midnight the storm reached us; never saw such marvellous lightning effects; all directions; one incessant blaze of glory; mostly horizontal discharges; saw several streaks turn back on themselves * * * "

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* We are indebted for the use of a number of these pictures to the journal *Electricity.*

The "tree form" (5) will probably explain the production of marks upon the bodies of persons struck by lightning, which have hitherto been supposed to be photographs of actual trees or branches.

Examination of the discharges upon the negatives by means of a strong lens discloses the presence of a transparent line running along its length. Whether this is due to photo-chemical action, or whether the lightning is so divided, I am unable to determine.

When lightning has once opened up a path in space, there usually follows immediately along the same line a series of discharges. If the camera be moved across its path the resulting photograph is liable to show a number of parallel ribbons of lightning, which has given rise to the opinion that it is not an instantaneous flash of light, but a burning streak of flame. No. 6 clearly shows statified lines near its lower extremity, although in this case the camera was rigid at the time of the discharge. I have often noticed the flight of bats during a thunder-storm, and have caught during what was apparently a single discharge of lightning a large number of instantaneous impressions of the wings of the bat in different positions clearly outlined against the sky.

In (11) a number of dark branches diverge from a light main stem. Whether this effect is the result of the reversal of the image upon the plate, or the branches represent yellow bands of light, branching from a white main stem, is an open question.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 16, 1891.*]

Hall of the Franklin Institute,
Philadelphia, December 16, 1891.

Mr. Jos. M. Wilson, President, in the chair.

Present, 182 members and sixteen visitors.

Additions to membership since last report, twenty-six.

The following nominations were made for officers, managers and members of the Committee on Science and the Arts:

For *President,*	(to serve one year), . .	Jos. M. Wilson.
" *Vice-president*	(" three years), .	Edward Longstreth, S. Lloyd Wiegand.
" *Secretary*	(" one year), . .	Wm. H. Wahl.
" *Treasurer*	(" " "), . .	Samuel Sartain.
" *Auditor*	(" three years), .	Wm. A. Cheyney, Francis LeClere.

For *Managers* (to serve three years),

Enoch Lewis,
John Lucas,
Wm. H. Thorne,
Edwin J. Houston,
George Burnham, Jr.,
Persifor Frazer,
John C. Trautwine, Jr.,
George C. Cresson,
Sam'l P. Sadtler,
John E. Codman.

For members of the *Committee on Science and the Arts* (to serve three years),

L. L. Cheney,
J. L. Gill, Jr.,
Carl Hering,
S. R. Marshall,
Wm. McDevitt,
Samuel Sartain,
Wm. H. Thorne,
S. L. Wiegand,
T. C. Smith,
C. M. Cresson,
C. E. Ronaldson.
Arthur Church,
J. M. Emanuel,
James Christie,
J. F. Haskins,
D. E. Crosby,

Dr. Herman Mehner, of Berlin, read a paper on a plan for generating motive-power, involving a new methed of transforming heat into mechanical energy. The paper aroused some discussion, and was directed to be referred to the Committee on Publications.

On Mr. Heyl's motion, the subject of the paper was also referred to the Committee on Science and the Arts for examination and report.

Dr. W. G. A. Bonwill read a paper, a description of a novel suggestion of his own in connection with aërial navigation.

Mr. J. M. Dodge gave a brief description of the Holmes lubricant bearing, referring for its claims to merit, to the report of the Committee on Science and the Arts (see this *Journal*, December, 1891). Mr. Dodge concluded his remarks with the exhibition of a varied selection of specimens of the bearing material.

Mr. Eadweard Muybridge, whose photographs of animal movements have attracted great attention, addressed the meeting, by request, on the subject of extending his work to the investigation of the mechanism of flight in insects, if the subject should appear, as seemed to him probable, to promise useful results, especially in the direction of the paper of Dr. Bonwill.

The remarks of Mr. Muybridge gave rise to considerable discussion, at the close of which Mr. Wiegand moved a reference of the subject to the Committee on Science and the Arts, to report upon the probable value of such an investigation as that proposed by the speaker. Carried.

Adjourned.

Wm. H. Wahl, *Secretary.*

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BEARING METAL ALLOYS.*

BY C. B. DUDLEY, Ph.D.,
Chemist to the Pennsylvania R. R. Co.

It is undoubtedly well known that what in technical language is called a "bearing," is a piece of metal (usually an alloy) which lies next to a revolving shaft or axle, or other revolving part of machinery, and sustains the load. The shape of the bearing may be such as to completely inclose the revolving shaft, or to cover only perhaps one-third of it. In car boxes the latter is true; the bearing rests on that portion of the axle, which is technically known as the journal, and on top of the bearing rests the weight of the car. In other situations, as for example in the case of crank-pins, and in many cases with shafting, the bearing metal encircles the revolving part, and has only as much play or space between it and the revolving part as is essential for smooth running. It is also doubtless well known that the space between the bearing and the revolving part, be it a portion of the axle, or of the crank-pin, or of a shaft, is commonly lubricated. It may also be fair to add, that what is commonly known as a "hot box" in railroad language, is in reality a hot bearing and the portion of the axle underneath it.

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* Abstract of a lecture delivered before the Franklin Institute.

The amount of metal used to make bearings is something enormous. To my knowledge, one large corporation uses not less than 1,000,000 to 1,250,000 pounds per year of bearing metal, and it can readily be seen why this should be so, from knowing that each bearing weighs from ten to fifteen pounds, and that each car has not less than eight, while some cars have twelve. Also, it is not at all uncommon for large railroads to build 5,000 cars at a time, which, as is readily seen, means 500,000 pounds of bearing metal. Still farther, it is a fairly good bearing metal that will not lose as much as a pound of its weight in a single bearing for every 25,000 miles that it goes under a car; so that the amount of new metal required to make up the loss by wear is something enormous, when the total car mileage, both freight and passenger, of the United States is taken into account. I have never seen any positive statement as to the amount of bearing metal used in a year in the United States, but the above considerations, in addition to the fact that bearing metal costs all the way from twelve to twenty cents per pound, will show that the money involved in bearing metals per year is a very large figure.

It has already been hinted that bearing metals are usually made out of alloys, and the question naturally arises why alloys are used. Why not use cast iron, or, indeed, some of the same metal of which the journal itself is to consist? I have never heard any entirely satisfactory reason, but it is commonly stated that a bearing and a journal of the same metal do not work well together. The wear is claimed to be more rapid, and the friction greater, when both the bearing and the journal are of the same metal. This would clearly explain why it would not be advisable to use wrought-iron or steel bearings. The same reasoning would not quite apply to cast iron, and, indeed, it is well known that in certain places in mechanics cast iron is used on cast iron, and also cast iron is used as a bearing metal where the journals are either wrought iron or steel. It seems fairly probable, however, that there is another reason beside the one already hinted at, connected with the wear and friction, why alloys are so largely used for bearings, namely, that alloys generally have a very much lower melting point than either cast iron or steel, and are therefore much more easily manipulated and gotten into the shape required. Moreover, there is still another reason that has been urged with a good deal of force, namely, that the journal is usually much more valuable than the bearing; that is to say, when the journal has worn a certain amount, the whole axle, crank-pin, or shafting perchance, must be replaced, so that the actual value of the axle, crank-pin or shafting is represented by a a thin layer of metal at the journal. If, now, a metal is used as bearing metal that increases the wear of the journal, the total loss will be much greater than if a metal is used, which itself wears away rapidly, but allows the journal to wear more slowly. This is believed to be the case with alloys. The bearings themselves are easily replaced, the journals are more difficult to replace, and are much more expensive, taken as a whole, and consequently it is good policy to use for a bearing metal something which will take the wear, rather than have it appear in the journals.

It may not be amiss to state what may be regarded as a good bearing metal. There may be five characteristics of a good bearing metal.

(1) The bearing must hold up the load. It is doubtless well known that in railroad practice, the pressure per square inch on the bearing metal is frequently as high as 350 to 400 pounds per square inch, and consequently it is absolutely essential that the bearing metal should be of such a nature that it will sustain this pressure without distortion. Moreover, it is doubtless well known that in ordinary railroad

practice, when the journal of the axle becomes somewhat worn, and it becomes necessary to put on a new bearing, there is not a perfect fit between the bearing and the journal since the bearings are all bored to the same radius, it being impossible to bore them for all possible conditions of worn journals. It follows that the bearing only touches the journal theoretically along a line, but actually the amount of surface involved is considerably more, and as most bearings in modern practice are lined with a coating of lead about one-eighth inch thick, it is only a short time before a good contact, embracing pretty nearly all the surface, is formed. But it is clear that the strain introduced in the bearing when it is put on a journal somewhat smaller than the radius to which the bearing is bored has a tendency to break the bearing in two lengthways, and the metal must therefore be of sufficient strength to resist this strain. Metallic lead, and indeed many of the white metal alloys, consisting of lead and antimony, lead, tin and copper, etc., are rarely used, so far as our knowledge goes, in car-journal bearings on this account, namely, although they may be good for certain reasons, they are hardly sufficiently strong, nor will they sufficiently well hold up the load to enable successful bearings to be made of them. They are frequently used, however, as linings, from one-eighth to possibly one-quarter or three-eighths inch thick, in a shell of stronger metal. Such composite bearings are very good, but their superiority over a bearing of the proper kind of metal does not seem to be sufficient, so far as my knowledge goes, to warrant the trouble of making the composite bearings.

(2) Another requisite of a good bearing metal is that it does not heat readily. Upon this point there is not as much information as could be desired. I have known of experiments with trial bearings in which three out of four heated within the first day or two, but it is always an open question as to whether this is due to the metal or some other concomitants of the service. It is also known by actual test on a large number of bearings that the old copper-tin bearing metal of seven parts copper to one of tin, results in a very much larger percentage of hot boxes than some of the alloys,

which will be mentioned later on. The general tendency of all the information which is at hand on this subject, is that the harder the bearing metal is, the more readily it will heat, or to put it in another form, the softer the alloy the less liability there is for the bearing to get hot in service.

(3) Another important requisite of a good bearing metal is that it shall work well in the foundry. It may, perhaps, make this point clear if I explain that bearing metal is usually melted in crucibles, holding from 100 to 500 pounds each, the crucible being placed in a hole made for the purpose above a grate, and surrounded with burning coal or coke. It is customary to cover the pot with the bottom of an old crucible, and to spread over the top of the molten metal, pounded charcoal. Yet despite these precautions, it is very common for the metal in the crucible, during the process of melting, and after it has become melted, to take up large quantities of oxygen from the air, forming oxides of the metal. When this takes place the castings made from such metal are always more or less spongy and inferior. It should be stated that with careful foundry practice, namely, with sufficient care in the melting to keep the metal well under pulverized charcoal, and also after the pot is taken from the fire to stir it thoroughly with pulverized charcoal, adding perhaps a little bit of metallic zinc, this difficulty can be largely overcome, but with a foundry where a large output is expected every day, the necessary care and time to secure solid castings with certain alloys, very seriously interferes with the work, and in many cases cannot be given, so that from the foundry standpoint, it is highly important, that the bearing metal used should be such a one as will give solid castings with the least possible effort and care in the foundry. So far as my knowledge goes, two things as constituents in bearing metal lead to this result: (1) from one to two per cent. of zinc in almost all the alloys used as bearing metal, makes it much easier to get sound castings, than if the zinc is not present; (2) the addition of a small amount of phosphorus either in the form of phosphor-tin, or in fact in the form of any of the phosphorized alloys to be obtained in the market, is always valu-

able for this purpose. The latter, namely, the phosphorus, is to our minds one of the principal elements of value in the well-known alloy "phosphor-bronze bearing metal." It is probably beyond question that with ordinary foundry practice a very much larger percentage of sound castings will be obtained from using the phosphor-bronze bearing metal, than from using the same constituents without the phosphorus.

(4) A good bearing metal should show small friction. Upon this point it may be urged that the friction is almost wholly a question of the lubricant used, and all the experiments that I have seen confirms this view to a greater or less extent, namely, that the largest portion of the friction between a bearing and a journal, is a function of the lubricant used. On the other hand, the nature of the bearing metal does certainly have an influence, and a good bearing metal is one which makes that element of the friction depending on the bearing metal as small as possible. I do not know of much experimentation on this subject. Such experiments are extremely difficult to make on account of the large number of variables, notably temperature, quantity of oil between the surfaces, pressure, speed, relative smoothness of the journal and bearing, etc. It is very greatly to be desired that careful experimentation in this field should be made.

(5) It is extremely important that a bearing should give high mileage with small loss of metal by wear. It has already been stated that the average bearing metal used under cars loses one pound for every 25,000 miles that the bearing goes. Many bearing metals wear much faster than this, and some slower, but other things being equal, no one will dispute that that bearing metal is best which wears the slowest. Some data on this point will be given a little further on.

The common metals from which alloys are made for bearings may, perhaps, be enumerated as follows: Copper, tin, lead, zinc, antimony, iron and aluminium. It is, of course, possible for manganese, silicon, bismuth, mercury, cadmium, nickel, cobalt, sulphur, arsenic and phosphorus to occur either as essential or accidental constituents of bearing metal alloys. The last two are not rare, and are purposely used. The combinations of these are quite numerous, and it will be observed that the possibilities of combination are very great. There is not only the different kinds of metal, but the different proportions. During my experience, now of some fifteen years, there have been analyzed in the laboratory of the Pennsylvania Railroad Company, a good many bearing metals under various names, and for the sake of record some of these analyses are given, as follows:

CAMELIA METAL.

	Per Cent.
Copper,	70·20
Tin,	4·25
Lead,	14·75
Zinc,	10·20
Iron,	0·55

ANTI-FRICTION METAL.

Tin,	98·13
Copper,	1·60
Iron,	trace

WHITE METAL.

Lead,	87·92
Antimony, by difference,	12·08

METAL FOR LINING CAR BRASSES.

Lead,	84·87
Antimony,	15·10
Tin,	trace

SALGEE ANTI-FRICTION METAL.

Zinc,	85·57
Tin,	9·91
Copper,	4·01
Lead,	1·15

GRAPHITE BEARING METAL.

Lead,	67·73
Tin,	14·38
Antimony,	16·73
Iron,	not determined
Graphite,	none

ANTIMONIAL LEAD.

	Per Cent.
Lead,	80 69
Antimony, by difference,	18·83

CARBON BRONZE.

Copper,	75·47
Tin,	9·72
Lead,	14·57
Carbon,	possible trace

CORNISH BRONZE.

Copper,	77·83
Tin,	9·60
Lead,	12·40
Zinc,	trace
Iron,	trace
Phosphorus,	trace

DELTA METAL.

Copper,	92·39
Tin,	2·37
Lead,	5·10
Iron,	0·07

MAGNOLIA METAL.

Lead,	83·55
Antimony, by difference,	16·45

Traces of iron, copper zinc, and possibly bismuth.

AMERICAN ANTI-FRICTION METAL.

Lead,	78·44
Antimony,	19·60
Zinc,	0·98
Iron,	0·65

TOBIN BRONZE.

Copper,	59·00
Zinc,	38·40
Tin,	2·16
Iron,	0·11
Lead,	0·31

GRANEY BRONZE.

Copper,	75·80
Lead,	15·06
Tin,	9·20

DAMASCUS BRONZE.

Copper,	76·41
Tin,	10·60
Lead,	12·52

MANGANESE BRONZE.

	Per Cent.
Copper,	90·52
Tin,	9·58
Manganese,	none

AJAX METAL.

Copper,	81·24
Tin,	10·98
Lead,	7·27
Phosphorus or arsenic,	0·37

ANTI-FRICTION METAL.

Lead,	88·32
Antimony,	11·93

HARRINGTON BRONZE.

Copper;	55·73
Zinc,	42·67
Tin,	0·97
Iron,	0·68

CAR BOX METAL.

Lead,	84·33
Antimony,	14·38
Iron,	0·61
Zinc,	trace

HARD LEAD.

Lead,	94·40
Antimony,	6·03

PHOSPHOR-BRONZE.

Copper,	79·17
Tin,	10·22
Lead,	9·61
Phosphorus,	0·94

EX. B METAL.

Copper,	76·80
Tin,	8·00
Lead,	15·00
Phosphorus,	0·20

It will be understood that the above analyses represent many metals offered by many different parties, sometimes under the same name. These analyses are selected from the many that have been made in the laboratory of the Pennsylvania Railroad, during the last twelve or fifteen years, and are simply put on record for whatever value they may have. It will be observed that copper, tin, lead, antimony and zinc, are the common metals used, and that iron is not a rare constituent. In some cases where there were very small amounts of other metals, they have not been determined, and sometimes may fairly be regarded as impurities. At other times perhaps they are essential constituents. I know of one or two cases where this latter is claimed, but our experiments have not gone far enough to prove whether these small amounts of other constituents are of value or not. On the other hand, it is well known that a small amount of iron imparts to a copper-zinc alloy quite wonderful properties. In the case of the so-called Harrington bronze, the analysis of which is given above, the alloy after it had been rolled, actually had a tensile strength of 75,000 pounds per square inch, and an elongation of about 20·00 per cent. in a two-inch section. Quite a large number of other alloys have either been examined qualitatively, or put on trial during the last fifteen years. Aluminium-bronze has not yet been tried, but it is now under consideration.

In view of the quite large number of metals which may be used to make alloys, and in view of the different properties which result from different proportions of these metals in the same alloy, it is perhaps not strange that the whole question of bearing metals, should be regarded as more or less uncertain. What ones of these five or six different metals shall be combined to make a successful bearing metal, and shall we use them all in the same alloy, or shall we use part, and more important than all, perhaps, after we have decided what metals shall be used in the alloy, what proportion of each shall be used. It is perhaps not too much to say that this difficult problem cannot be regarded as completely worked out as yet. A good deal has been done but much remains to be done, and it is entirely possible that future knowledge, as the result of careful experiment, will change many of the views that are now held in regard to the composition of bearing metal alloys.

It is undoubtedly entirely natural that in attempting to find out what the best bearing metal is, the ones in use should be taken as the starting point. This was the case with the experiments that have been conducted on the Pennsylvania Railroad. Most people are aware that fifteen or twenty years ago, the standard metal used in car bearings, and other places was a simple copper-tin alloy, containing seven parts of copper to one of tin. Indeed, some railroads, if I am rightly informed, and some builders of machinery, even at the present time use cannon bronze, or the seven to one copper and tin alloy as bearing metal. It will be seen as I proceed that we regard this as a serious mistake; that while perhaps we do not know what the best bearing metal is, we do know something very much better than the copper-tin alloy.

It will, perhaps, be essential to describe the method of experimentation, before proceeding, to show what modifications in the copper-tin alloy have been made use of in trying to throw some light on the question of the best bearing metal alloy.

The method in all cases has been to have a certain number of bearings made of a standard bearing metal, which will be described later on, and the same number of bearings of the experimental metal. These bearings were placed on opposite ends of the same axles, either on locomotive tenders or on cars, one-half of the standard and experimental bearings being on one side of the car, and the other half being on the other side, but in all cases a standard bearing and an experimental bearing on opposite ends of the same axle. The bearings were all carefully weighed before going into service, and after a sufficient lapse of time were taken out and re-weighed. At first an attempt was made to give the loss of metal by referring it to the mileage, but the method of comparison was ultimately adopted, as giving results free from any possible difficulties introduced by mileage, so that all the results which we obtained are strictly comparative.

The standard bearing metal is what is known in the market as phosphor-bronze bearing metal, technically described by the Phosphor-Bronze Smelting Company as the "S Bearing Metal." This metal contains, approximately, 79·70 per cent. of copper, ten per cent. of tin, 9·50 per cent. of lead, and about 0·80 per cent. of phosphorus. It is, of course, a fair question, and one which has not been overlooked, whether the standard bearing metal gives uniform wear. A large number of experiments have been made on this point, the result being that the average wear of standard phosphor-bronze, compared with the mileage, is best expressed by saying that the phosphor-bronze bearing metal loses one pound of metal, worn off, for every 18,000 to 25,000 miles of travel. This, it will be observed, shows a discrepancy in the wear of the standard phosphor-bronze bearing metal, and this fact led us to abandon the method of making comparisons by mileage. The reasons for the discrepancy are not hard to find: (1) The pressure per square inch in all tests was not the same, and consequently the wear would not be the same. On the other hand, with bearings on the opposite ends of the same axle, the pressures per square inch are approximately the same. (2) The state of the lubrication in different cars and engines, which is more or less characteristic of different parts of the road, is a very important variable, and undoubtedly goes far towards explaining the differences in mileage above given. This variation in the state of lubrication is not so apt to be characteristic of opposite ends of the same axle, as it is of different cars and locomotives. I am inclined to think, therefore, that the assumption that standard phosphor-bronze is sufficiently uniform in its behavior to warrant its being used as the basis of comparison will not lead us into serious error, at least if we confine ourselves to a direct comparison of the loss of metal obtained from standard bearings on one end of the axles and experimental bearings on the other end of the same axles. Usually sixteen bearings of each kind were put in service as a preliminary experiment, and if the metal proved at all favorable on this preliminary trial, a larger trial, embracing fifty or 100 bearings of each kind, was put in service. The preliminary trials were usually made on locomotive tenders, where the bearings get the best possible care. The larger trials were more commonly made on cars. Of course, owing to the exigencies of the service, it sometimes happened that some of the bearings put in use were not returned to be weighed. This was more true where bearings became heated, and were removed at different points along the line, than at the regular inspection points. Whenever, from any cause, a bearing was missing, its opposite was not taken into account, so that in reality in the results given the comparisons are strictly between the same number of standard and experimental bearings on opposite ends of the same axles. Sometimes as high as one-half the bearings in an experimental lot would be lost. In other cases nine-tenths would be returned.

[*To be continued.*]

EXPERIMENTS MADE TO ASCERTAIN THE SPECIFIC VOLUMES OF THE SATURATED VAPORS OF WATER, BISULPHIDE OF CARBON, AND ETHER, TOGETHER WITH VARIOUS MEASURES CONCERNING THE LATTER; ALSO THE DETERMINATION FROM THE EXPERIMENTAL DATA THUS OBTAINED OF THE MECHANICAL EQUIVALENT OF HEAT.

By A. Perot.

Translated by Chief Engineer Isherwood, U. S. Navy.

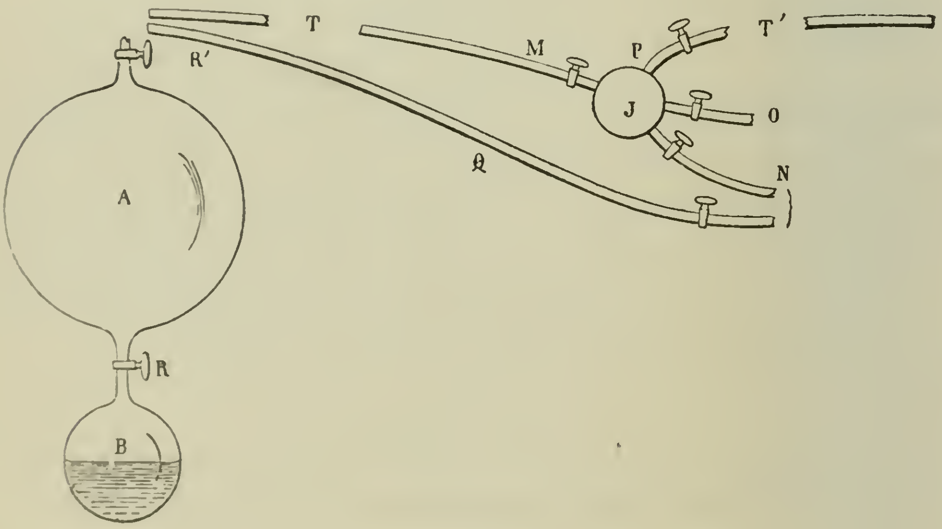
[*A thesis presented to the Faculty of Sciences of Paris.*]

[*Concluded from p. 68.*]

Second Method.—I shall show the principle of this method by describing an imaginary experiment with it.

Suppose a receptacle *A* (*Fig. 5*), of known capacity put in communication by means of the cock *R* with a reservoir *B* containing some liquid, and by means of the cock *R′*, either with a pneumatic machine or with the atmosphere. The apparatus having been raised to a certain temperature, and a vacuum made in *A*, if the cock *R* be opened, the cock *R′* remaining closed, *A* will be filled with saturated vapor, owing to the presence of the liquid continuing in *B*. If *R* be now closed a known volume of saturated vapor will be isolated. Through the cock *R'*, and by the aid of the pneumatic machine, draw out this vapor over absorbents placed between the cock and the machine. Knowing the volume of the receptacle *A*, and the increased weight of the absorbent tubes, which increase is the weight of the vapor that occupied the space *A*, there can be obtained by dividing the one into the other the specific volume of the saturated vapor. This method easily allows repetition of the trials, for there could be accumulated in the absorbent tubes the vapor corresponding to any number of trials, for which purpose there

FIG. 5.

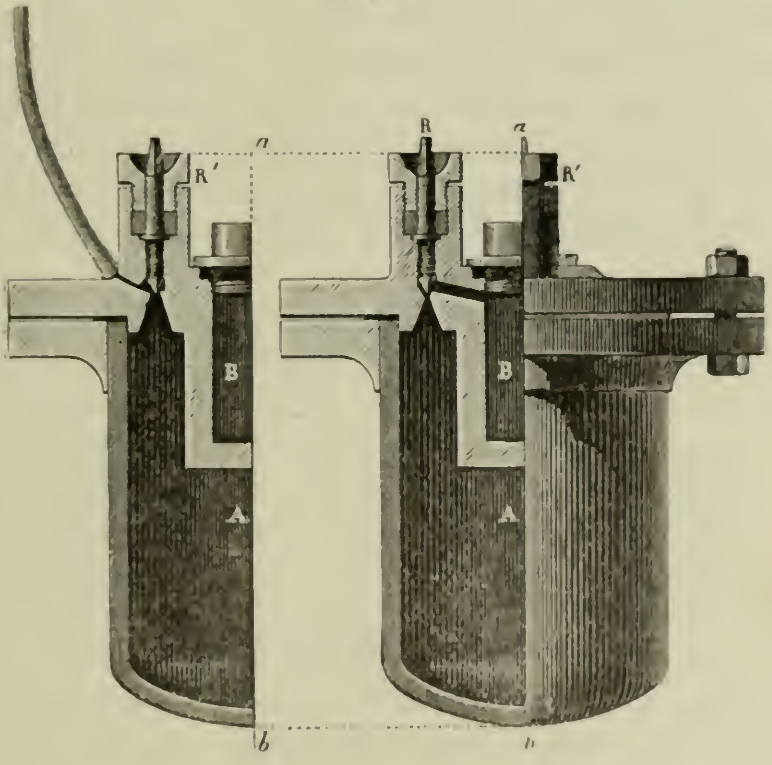


would only be required to make anew the vacuum in *A*, and recommence the operation in the same manner as before.

To realize the method just described, I employed the following apparatus (*Fig. 6*): A pot-shaped boiler of a little more than one litre capacity being closed by a bronze cover, constitutes the space *A*. The reservoir *B* forms part of the cover and projects downward into the boiler, its temperature being consequently exactly the same as that of the boiler; it is fastened by screws. The cocks *R* and *R'*, which are the analogues of those having the same letters in the preceding figure, are packed cocks having their stuffing boxes filled with mixed cork and talc to avoid any trace of grease; for this purpose, too, all the joints are made with lead. The boiler is plunged into a water-bath, where it is supported upon points and held fixed so as not to move when the cocks are turned. The entire interior is gilded so as to certainly avoid any attack of the metal by the vapor or the liquid, by presenting a continuous surface of a homogeneous metal but little liable to be affected.*

The following is the manner of making an experiment on ether (*Fig. 5*):

Fig. 6.



From a central point of junction *J* there goes a tube *M* containing the absorbents *T* and uniting with the cock *R'*. Also the tube *N* uniting with the mercurial pneumatic machine. Also the tube *O* uniting with the Carré machine. Finally, the tube *P* united by its end to a series of tubes *T'*, destined to arrest the atmospheric carbonic acid and aqueous vapor. These tubes contain two pots of caustic potash, two pots of sulphuric acid, four large tubes with sulphuric pumice, a column of anhydrous potassa of about thirty centimetres, and a column of the same length of phosphoric acid. A last tube *Q* allows the space *A* to be put in direct connection either with the mercurial machine or the Carré machine, without passing through the series of tubes *T*.

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* This apparatus was constructed with great perfection by Mr. Ducretet.

The absorbent tubes that I have employed for the vapor of ether are, commencing at the boiler, the following: from two to four Liebig tubes containing pure sulphuric acid for absorbing the vapor, a tube with lime mixed with some soda for absorbing the sulphurous acid which might be disengaged by the action of the sulphuric acid on the ether, a tube of sulphuric pumice preceding two tubes of phosphoric acid destined to serve as witness tubes. One of these tubes at least ought not to vary in weight. The mass of ether absorbed has been calculated from the increase in the weight of all the tubes comprised between the cock *R′* and the first of the tubes of phosphoric acid, which latter has not varied in weight.

As an example, the following are the results of an experiment comprising two tubes of sulphuric acid:

No. of Tube.	*Name of Absorbent.*	*Gain.* *grams.*	*Loss*
1, . . .	Sulphuric acid, ...	2·56625	0
2, . . .	Sulphuric acid, ...	0·0070	0
3, . . .	Lime mixed with some soda, ...	0·0030	0
4, . . .	Sulphuric pumice, ...	0·0000	0
5, . . .	Phosphoric acid, ...	0·0000	0

Mass of ether absorbed, 2·5762 grams.

As shown above, the ether is absorbed almost integrally in the first acid tube, at least when the acid is newly prepared, as was the case in the experiment cited; the acid should be changed with each experiment because after being once used it disengages sulphurous acid, a perturbation that should be avoided.

I have said that with this apparatus a method of repetition could be employed, nevertheless, I have limited myself to one time only, because in a single simple experiment lasting about four hours, the disengagement of sulphurous acid which I have mentioned above commences at the close of the second experiment, and I considered prudence required it to be avoided, notwithstanding the presence of the lime and soda.

The following is the manner of making the experiment: I raised the water-bath to the desired temperature and maintained it constant as nearly as possible for exactly an hour; in general, the variations did not exceed $\frac{1}{20}$°. During this time I made a vacuum in the boiler by means of the tube *Q*, so that the pressure of the air therein did not exceed one millimetre of mercury; this done, I closed the cock *R′* and opened *R* progressively. I left the boiler in communication with the vapor generator *B* about an hour when I closed cock *R* and opened *R′*. I made by means of the Carré machine the vacuum very slowly in the absorbent tubes. When the pressure was not more than 3·5 centimetres of mercury, I interrupted, by manipulating the cocks, the communication of the apparatus with the pumps, and I allowed to enter very slowly the air purified by passing through the tubes *T′*. Equilibrium having been established with the atmosphere, I re-made the vacuum—always to 3·5 centimetres—and allowed the air to reënter, and so on; in every experiment I made, the air was let in four times, and consequently the vacuum was made five times.

The quantity of air thus remaining in the boiler is negligable. If, in fact, there be admitted that in an approximate calculation the law of Mariotte, and the law of the mixture of gases, can be applied to the vapor and to the air, the successive weights of vapor π, π_1, π_2, etc., contained in the boiler will be proportional to the successive pressures h, h_1, h_2, etc., of this vapor. The ratio of one of these pressures to the preceding being the ratio to the atmospheric pressure of the pressure remaining in the apparatus when the communication with the pump is interrupted; that is to say, $\frac{3·5}{76}$ or about one-twentieth, we should have

$$\frac{\pi_2}{\pi} = \frac{\pi_2}{\pi_1} = \frac{\pi_3}{\pi_2} = \frac{\pi_4}{\pi_3} = \frac{1}{20} \text{ and } \frac{\pi_4}{\pi} = \left(\frac{1}{20}\right)4 = \frac{1}{160000}$$

a quantity absolutely negligable.

Gauging.—The principal difficulty of these experiments is in the gauging of the capacity *A*. Two processes have been followed for that purpose.

(1) The determination of the mass of the distilled water

that fills the boiler at the temperature of 30°, which was the temperature of the experiments.

(2) The determination of the mass of pure carbonic acid contained therein under known conditions of pressure and temperature.

Gauging with Water.—The cover of the boiler is lifted and about 500 cubic centimetres of distilled water are put therein, then the cover is replaced and the water is boiled for a considerable time, the evacuating tube previously plunged into the water being maintained hot. The boiler is thus filled in the same manner as a thermometer. At the end of about an hour the whole apparatus is raised to the temperature of 30°, when the two cocks are opened. The cover is then cautiously removed and the water, taken out by a pipette, is received in a vessel previously tared. The sides are carefully dried by absorbing paper tared with the vessel, and the vessel and the paper are placed upon the scales. Two successive operations thus gave 1136·50 and 1137·13 cubic centimetres: they are the largest numbers obtained. As the sole errors that can be made arise from bubbles of air in the interior, or from a leak of water, and would consequently be errors of deficiency, the largest determinations must be considered as the nearest exact.

I have taken for the value of the volume the mean of the two preceding determinations, namely 1136·90 cubic centimetres.

Gauging with Carbonic Acid.—The carbonic acid, which should be perfectly pure, cannot be obtained by the ordinary processes as they always furnish it with a mixture of air. It was produced by the reaction of a solution of pure carbonate of soda freed of air, on pure sulphuric acid spread out and also freed of air. The solution of carbonate of soda, contained in a balloon, fell drop by drop, by means of a siphon fitted with a cock, into a large balloon containing the sulphuric acid. The two ends of the siphon were drawn out and recurved in such a manner that each of the two liquids could be boiled without causing it to prime. The carbonic acid produced passes first into a small balloon containing a little sulphuric acid for absorbing the water vaporized during the boiling of the extended sulphuric acid, thence the gas passes into a vessel through sulphuric acid, and traverses four tubes of sulphuric pumice. The apparatus can operate about ten hours without need of renewing the liquids. All the evacuating tubes were cut true and level with the stoppers, so that they had no reëntering angles. I assured myself that a litre of carbonic acid contained at the moment of the trial only about thirty cubic millimetres of gas not absorbable by the potassa, which gas was probably hydrogen derived from the action of the sulphuric acid upon some traces of organic matter.

I allowed the gas to pass freely during six or seven hours into the boiler with a moderate speed, at the end of which time it contained on leaving the apparatus only the traces of other gas just described. I now closed the receiving cock and left the interior of the apparatus for some instants in communication with the atmosphere by means of a long tube filled with carbonic acid; then I closed the second cock and operated exactly the same as for density of vapor.

The absorbent tubes employed were four tubes of caustic potash, one tube of lime mixed with some soda, one tube of sulphuric pumice, and two tubes of phosphoric acid.

The following are the results given by two experiments:

Temperature. *Degrees*	*Weight of Acid Absorbed.* *Grams.*	*Volume.* *Cubic Centimetres.*
30·92	1·9930	1136·13
30·90	1·9928	1136·05

Mean, 1136·09 cubic centimetres.

a value very near that which I had found in operating with water, because the boiler having been compressed 0·012 centimetre,* its volume was diminished 0·9 cubic centimetre.

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* The fraction of a millimetre was ascertained by the following artifice: I always made sure that the cover was parallel to the flange of the boiler by inserting a brass wedge between them all around so as to be in exact contact at the same distance from the back of the wedge. By doing this before and after the cover was screwed up, I obtained the thickness of the wedge at the edge of the cover for the two times, the difference between which, observed through a microscope, gave 0·012 centimetres for the value of the correction to be made.

The following are the results obtained for the specific volume of the saturated vapor of ether, in operating from 27° to 35°:

Temperature. Degrees.	*Specific Volume.*	*Observations.*
27·66	441·3	
28·60	423·9	
29·375	410·4	
29·72	405·1	
30·02	399·9	Double experiment.
31·50	377·2	
34·12	351·2	

In comparing these numbers with those I obtained by the first method, I have found a complete accordance. For example, the two first experiments made, one at 30° (first method), the other at 30°·02 (second method), gave, the one, 400 cubic centimetres, the other, 399·9 cubic centimetres, as the value of the specific volume.

This accordance gives an almost absolute certainty that the two methods do not contain any errors of system, for the apparatus were very different. In the one, the vapor is in contact with a glass surface, and, in the other, it is in contact with a golden surface. Had there been any sensible action by the surface, it is more than probable that it would have varied with the kind of surface. This is the most important justification of the two processes; it authorizes me to consider the numbers found as exact, and to apply them to the calculation of the mechanical equivalent of heat.

I stated at the commencement of this memoir, that Herwig thought a relation existed between the density of dry vapor and the density of saturated vapor. To show within what limits such an hypothesis is admissible, there suffices to cite the numbers deduced from my experiments for the value of the constant *C* in his formula

$$PV = CP_1 \; V_1 \sqrt{T}$$

or

$$\Delta_1 = C \Delta \sqrt{T}$$

in which $P_1 V_1 \Delta_1$ relate to the saturated vapor, and P, V, Δ relate to the dry vapor:

Name of Liquid.	*Temperature. Degrees.*	*C.*
Water,	68·2	0·0527
	88·6	0·0525
	98·1	0·0526
	99·1	0·0528
	99·6	0·0527
	101·5	0·0526
Ether,	30·0	0·0428
	57·9	0·0551
	85·5	0·0583
	110·5	0·0609

For the vapor of water the accordance is sufficient; but for ether C varies in an interval of 80° nearly half of its value at 30°.

CHAPTER II.

Determination of the Value of the Mechanical Equivalent of Heat.

By applying to a mixture of a liquid with its vapor the principle of the equivalence and the principle of Carnot, a relation is obtained which can also be deduced from the equation of Thomson: it is,

$$\frac{dT}{dt} L = \frac{1}{E} T (u' - u) \frac{dp}{dt}$$

This relation contains one independent variable t, the Centigrade temperature; four quantities, functions of this temperature, specific to the substance to which the relation is applied; L the heat of vaporization, u' and u the specific volumes of the vapor and of the liquid, p the pressure; the absolute temperature T, and a constant E, the mechanical equivalent of heat.

If T be supposed represented by the expression,

$$(273 + t), \quad \frac{dT}{dt}$$

becoming the unity, and if, for any particular value of t, there be introduced into the relation the system of values corresponding to

$$L, u', u \text{ and } \frac{dp}{dt}$$

it will contain no other unknown than E, and could be regarded as an equation permitting the determination of that quantity.

For a certain number of substances, and particularly for water, ether and the bisulphide of carbon,

$$L \text{ and } \frac{dp}{dt}$$

have been measured at different temperatures by Regnault and represented by empirical formulæ: u has been determined by other experimenters, and, finally, I have measured u' for these substances at certain temperatures; I am then able to calculate E, and the following are the results:

Name of Liquid.	*Temperature. Degrees.*	*Mechanical Equivalent of Heat.*	*Mean.*
Water, ...	68·20	424·6	423·95
	88·60	423·3	
	98·10	424·1	
	99·60	423·9	
	101·50	423·9	
Ether, ...	57·90	424·2	424·07
	85·50	424·0	
	110·50	424·0	
Bisulphide of carbon, . . .	84·60	424·5	424·50

The accordance between the different numbers of this table is as satisfactory as possible, if there be considered that they are derived from numerical data obtained by three experimenters on different specimens of the substances. and that the presence of impurities often difficult to remove, escaping even chemical reactions, can profoundly modify the physical properties of substances.

In order to avoid this cause of error, I proposed to determine for the same specimen of the substance the four quantities

$$u, \ \frac{dp}{dt}, \ L \text{ and } u'$$

entering into the preceding relation. Endeavoring to obtain the value of the closest possible approximation to the mechanical equivalent of heat, I ought to place myself in the best experimental conditions for diminishing as much as I could the errors that may have been committed in the determination of these quantities. It seemed to me that in the neighborhood of 30°, these measures could relatively be made without difficulty for ether; further, this substance is easily obtained and preserved pure; I have consequently chosen ether at 30°, and endeavored to obtain as exactly as possible the values of the four specific constants

$$u, \ \frac{dp}{dt}, \ L \text{ and } u',$$

by operating on a single specimen of this substance.

I will now rapidly describe the methods employed, and then present combined under a single heading, the interpretation of the different results obtained.

Purification of the Ether.—Two litres of purified ether were placed during two months in contact with sodium, then, after all disengagement of gas had ceased, I carefully distilled this liquid in contact with newly cut sodium, and thus obtained about 700 cubic centimetres of a liquid the whole of which distilled rigorously at the same temperature, and in which the freshly cut sodium remained intact during ten days. At the end of that time it showed a slight alteration, due, doubtless, to the absorption of the aqueous vapor of the atmosphere by the anhydrous ether during the necessary manipulations of the experiment.

Measure of the Specific Volume of Liquid Ether and of its Coëfficient of Dilatation at 30°.—The method employed is derived from the method of the stem thermometer.

I constructed with a thermometric tube whose stem was graduated into equal lengths, a mercurial thermometer which I compared between 20° and 50° with a standard Baudin thermometer and afterwards with a thermometer that I had previously compared with an air thermometer. From these comparisons I deduced the value in degrees of each division, and constructed a trace by taking for abscissæ the numbers corresponding to each division of the thermometer for equal weights, and for ordinates the values of these divisions. The trace thus obtained was a straight inclination to the axis of the divisions; I established by this process that the tube was regularly conical. In applying the method of least squares to the results found, I have obtained for the value of one division in degrees the formula

$$x = 0{\cdot}6425 + (120 - n)\,0{\cdot}00034$$

n being the division read.

The weight of mercury contained in the reservoir and in the stem up to division 57, was 22·6090 grams, the weighing being done in a manner that rendered it certain within 0·0003 gram; the volume of that part at 0° was then 1·67166 cubic centimetres, the first five figures being exact, and the volume of division 120, 0·0001977 cubic centimetres. I had supposed the coëfficient of the dilatation of the glass equal to 0·000025; but in order to assure myself of its accuracy, I weighed a column of mercury comprising fifty divisions and found 0·0099 gram to nearly one-tenth of a milligram, then, as this weight, calculated according to the data above given, should have been between 0·0100 and 0·0099 gram, the agreement was satisfactory.

This gauging done, I emptied the mercury out of the thermometer and introduced the ether, after which I compared the thermometer anew with the standard. From this comparison I have deduced the coëfficient of dilatation between 29° and 31°, and find it 0·0017524. The thermometer filled with ether was weighed, then emptied, refilled and weighed again. The two weights of the contained ether were 1·2466 and 1·1755 grams, which give for the density the values 0·7035 and 0·7025; the mean of these determinations, 0·7030, has been taken for the value of the density. The specific volume is 1·422 cubic centimetres.

Measure of $\frac{dp}{dt}$.—Two methods have been employed to measure

$$\frac{dp}{dt}$$

(1) that which consists in measuring the tension of vapor p at different temperatures for the purpose of representing

empirically the value of p by a formula, and to deduce from it the first differential coëfficient

$$\frac{dp}{dt}$$

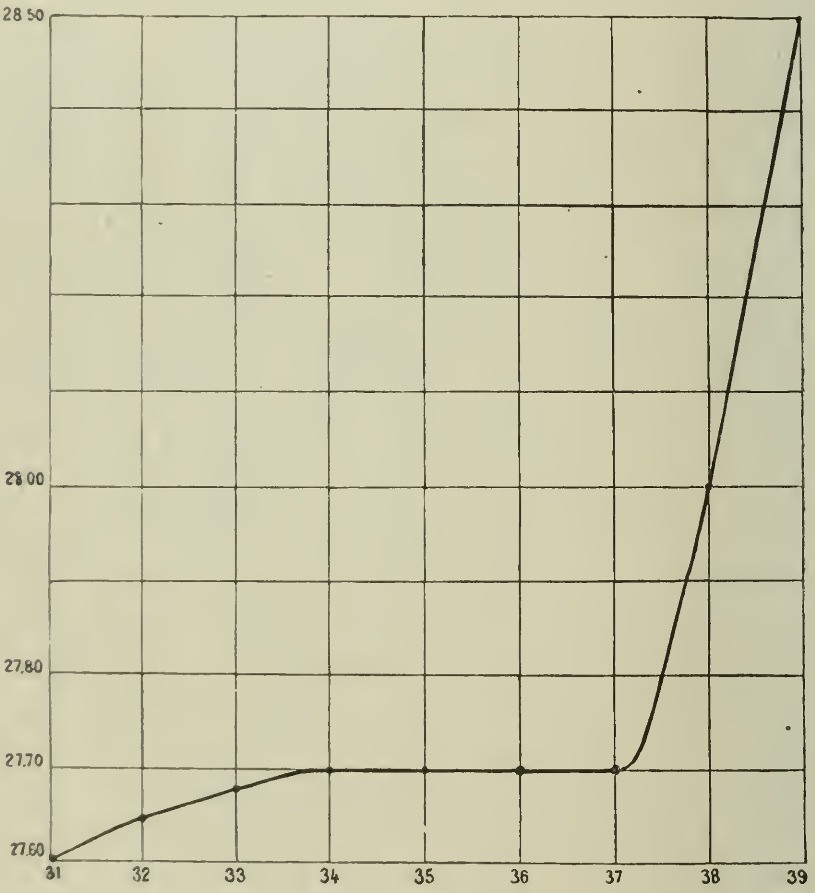
(2) a particular method allowing the direct determination of

$$\frac{dp}{dt}$$

which will be described in the second place.

First Method.—The method employed for measuring the tension of vapor is the method by boiling. The apparatus—entirely of glass—is composed of a balloon of about 100 cubic centimetres capacity, containing the ether; a Gernez gas bell to facilitate and regulate the ebullition was placed in the balloon. A thermometer A divided into tenths of a degree was immersed in the vapor immediately above the liquid. The neck of the balloon was soldered laterally to an upward Liebig refrigerator whose free extremity communicated with a large balloon of a score of litres capacity placed in a water-bath of constant temperature. To one part of this reservoir was attached the manometer of the Joly air thermometer, graduated on ice in such a manner as to avoid the errors of parallax without necessitating the use of a cathetometer; and to another part, by means of a hermetically sealed tube, was attached a machine for rarefying the gas. The apparatus had only two cork stoppers, the tightness of which was assured by means of mercury. The balloon containing the ether was half immersed in a large water-bath, so as to prevent the radiation upon the thermometer of the flame that had been placed directly beneath the balloon. The temperature of the thermometer A depended upon three quantities: the radiation R of the water-bath upon the thermometer, the radiation R' of the thermometer on external cooler objects, and the heating or cooling of the thermometer by the action of the vapor into which it was immersed. If R is less than R', the cooling of the thermometer is compensated, at least in part, by the liquefaction of the vapor; if, on the contrary, R is greater than *K'*, the thermometer can only be cooled by the convection of the vapor, a much less powerful action than liquefaction. To show how the temperature of the thermometer *A* varies with that of the water-bath, I placed a thermometer *B* in the latter and observed the two instruments simultaneously while increasing, from five minutes to five minutes, the temperature of the water-bath 1°. The trace (*Fig. 7*) obtained by taking for abscissæ the indications of *B*, and for ordinates those of *A*, shows a horizontal part corresponding to a variation of about 4° of the temperature of *B*; this is the constant temperature that has been taken for the boiling temperature; the trace, previous to that part very little inclined by reason of the reheating power of the liquefaction, rises rapidly afterwards because the effect of the radiation is no longer counterbalanced by that

Fig. 7.



of the convection. The following are the numbers obtained during an experiment:

B. .	31	32	33	34	35	36	37	38	39
A. .	27·60	27·65	27·68	27·70	27·70	27·70	27·70	28·00	28·50

For all the measures I arranged the conditions to be such that the thermometer *A* marked the exact temperature of boiling; in this case, for example, so that the temperature of the water-bath was comprised between 35° and 36°.

The experiments, made with these precautions, gave the following results:

FIRST GROUP.	
Temperature. Degrees.	*Pressures in Centimetres of Mercury.*
26·41	56·644
27·51	58·146
28·31	59·901
29·21	61·886
29·71	63·103
30·21	64·290
30·71	65·536
31·21	66·634
31·71	67·826
32·21	69·086
SECOND GROUP.	
28·21	59·626
28·71	60·772
29·21	61·923
29·71	63·000
30·21	64·257
30.71	65·454
31·21	66·631
31·71	67·967
THIRD GROUP.	
28·21	59·619
28·71	60·781
29·21	61·924
29.71	63·015
30·21	64·272
30·71	65·448
31·21	66·630
31·71	67·915

Each of these groups of measures was made with *new* ether, and the uniformity of the results, very remarkable in the last two groups, shows the apparatus to have been thoroughly dried.

Second Method.—This method allows the determination to be separately made of the two terms of the relation

$$\frac{dp}{dt}$$

Imagine that we seek to measure the tension of the ether vapor at 30° with the apparatus just described under the head of "First Method," and that there was a slow reëntrance of air into this apparatus, the pressure would gradually increase and the temperature rise, so that these two quantities would be functions of the time.

Considering an infinitely small interval of time $d\theta$, we could write

$$dp = kd\theta$$

$$dt = k'd\theta$$

k and k' being the speeds

$$\frac{dp}{d\theta}$$

and

$$\frac{dt}{d\theta}$$

of the variation of the pressure and of the temperature. As t is only a function of p,

$$\frac{dp}{dt} = \frac{k}{k'}$$

If experiment showed that these speeds vary very slowly, we could, in place of infinitely small variations, consider variations finite but very small; that is to say, write

$$\Delta p = k\Delta\theta, \qquad \Delta t = k'\Delta\theta, \qquad (1)$$

and the relation

$$\frac{k}{k'}$$

could be directly measured. Let θ_1 be the time necessary for the pressure to increase to 0·1 centimetre; θ_2 that which corresponds to a rise of temperature of 0°·1; we should have

$$0{\cdot}1 = k\theta_1, \qquad 0{\cdot}1 = k'\theta_2,$$

whence

$$k\theta_1 = k'\theta_2$$

and

$$\frac{k}{k'} = \frac{\theta_2}{\theta_1} = \frac{dp}{dt}$$

we have then to measure only the relation of two times, a quantity independent of the chronometer employed.

The reëntrance of the air that I employed in the apparatus, was effected by means of a very fine capillary tube. I first investigated how the coëfficients k and k' varied; that is to say,

$$\frac{1}{\theta_1}$$

and

$$\frac{1}{\theta_2}$$

for successive intervals of time, and I am convinced that we can rigorously consider k and k' as constants and apply the equations (1) for considerable variations of pressure.

The following are the results of an experiment:

Manometer (mm.),	65	64	63	62	61	60	59	58	57
Times (seconds), .	155	238	324	408	492	576	662	745	829
Differences, . . .	83	86	84	84	84	86	83	84	

Mean of the differences, ... 84·25

Thermometer (degrees), ...	29·40	29·50	29·60	29·70	29·80
Times (seconds), ...	315	518	708	904	1,099
Differences, ...	197	196	196	195	

Mean of the differences, ... 196

Mean temperature, ... 29·60

The above show that for variations of θ_1 corresponding to a low maximum of eight millimetres of the manometer, the conditions are as previously stated.

We may write, therefore, that at 29°·60, the mean temperature observed, we have*

$$\frac{dp}{dt} = \frac{\theta_2}{\theta_1} = \frac{196}{84{\cdot}25}$$

The indications of the manometer are instantaneous, those of the thermometer are not; but, the temperature varying with regularity, there would be established a permanent *régime* in which the retardation of the instrument would be constant. Further, we can control the value of this retardation, because in diminishing the speed of the reëntrance of the air into the apparatus, we can vary the temperature as slowly as we wish. After having established the variations of temperature, we need not give them any further attention.

The method consists, then, in measuring with a chronometer arranged for making dots, or any other apparatus capable of registering time, the intervals necessary for obtaining, on the one hand, an increase of pressure of 0·1 centimetre of mercury, and, on the other hand, a rise of temperature of 0°·1; the quotient of these two times gives

$$\frac{dp}{dt}$$

expressed in centimetres of mercury.

The advantage of this method consists in only being obliged to detect the instant when a mercurial column corresponds with a unit division, and, consequently, of being able to dispense with estimating fractions of a division which is always a delicate matter: the thermometer and the manometer used in these experiments being graduated on the stem, made this detection easy. The precision is in one sense unlimited, because in diminishing the speed of the reëntrance of the air, the time for making the observation is increased; that is to say, the two terms of the relation

$$\frac{dp}{dt}.$$

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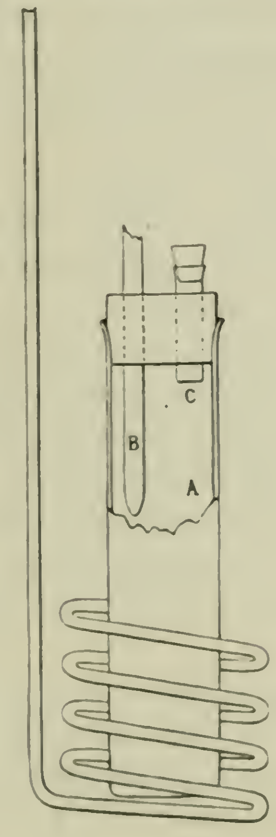
* I do not speak of ordinary corrections necessary to be additionally made.

The following are the results obtained in operating between 29° and 31°:

Temperature (degrees), . .	29·01	29·51	29·61	29·91	30·11	30·21	31·01
$\frac{dp}{dt}$ (cm. of mercury), . .	2·2770	2·3171	2·3252	2·3505	2·3677	2·3757	2·4422

Measure of the Heat of Vaporization.—The method employed for measuring the latent heat of vaporization, is one of those described by Berthelot in his *Essay on Chemical Mechanics.*

Fig. 8.



It consists in measuring the fall of temperature produced by the vaporization under a gaseous current of a determined quantity of liquid.

A laboratory tube *A* (*Fig. 8*), of thin brass containing the liquid, is placed in the calorimeter; the dry air which produces the vaporization penetrates into the apparatus through a glass tube *B*, passed very tightly through the cork stopper closing the tube *A*; it passes out at about two thirds of the height of the laboratory tube through a brass coil of about one metre length wound around the tube *A* and finally debouching into the atmosphere outside of the calorimeter. The cork of the large tube *C* is itself closed by a small cork.

The process of the operation is as follows:

The calorimeter is allowed to remain from three to four hours in a chamber heated to about 30°, the water of the enciente being maintained at a temperature between 33° and 35°: in the experimental conditions under which I operated, the heating of the water due to the excess of the temperature of the enceinte over that of the calorimeter nearly compensated the cooling due to the vaporization. At the end of the three or four hours there is introduced into the laboratory tube a phial containing a known mass of ether, the tube *B* being replaced. The water of the calorimeter is now agitated and the dry air passed through; the latter is dried in tubes containing sulphuric pumice, and is heated to 30° by its passage through a coil of lead pipe maintained at that temperature. At the end of half an hour the calorimetric thermometer is observed, and we wait, to commence the experiment, some ten or fifteen minutes, in order to start when the permanent regimen is established.

The stopper is then taken out of tube *C*, and the phial broken by a sharp iron rod; the tube is quickly reclosed, and the thermometer is noted from minute to minute during about a quarter of an hour, which is the time required for an experiment; and it is also noted for fifteen minutes afterwards.

The calculation for the correction has been made according to the directions given by Berthelot. As to that which regards the heat of vaporization, it has been made in the following manner:

Let $//$ be the weight of the calorimeter water, M the mass of ether vaporized, t_1 and t_2 the initial and final temperatures, t the temperature at any instant whatever; $\mapsto$ the reheating resulting from external action. Further, let dm be an infinitesimal mass of ether, whose vaporization corresponds to a variation dt of temperature and to a correction $d\theta$; we would then have

$$-H\,dt - H d\theta = L\,dm$$

or

$$-\frac{dt}{L} = \frac{dm}{H} + \frac{d\theta}{L}$$

For any given experiment, m, t and θ are functions of the time, L is the same because it is a function of t; we could then integrate the preceding relation within the limits of an experiment and write

$$-\int_{t_1}^{t_2} \frac{dt}{L} = \frac{\int_0^M dm}{H} + \frac{\int_0^\theta d\theta}{L_1}$$

replacing in the second term of the second member, L by its mean value L_1 during an experiment, a permissible approximation, this term being a correction.

In the first member we do not know the relation between L and t; but Regnault has shown that for ether this quantity can be represented by the formula

$$L = 94{\cdot}00 - 0{\cdot}07901\,t - 0{\cdot}0008514\,t^2.$$

There can be admitted, with what seems a sufficient approximation when the smallness of the coëfficient of the term in t^2 is considered, that for an internal of from 4° to 6° in the neighborhood of 30°, there can be put

$$L = a + bt,$$

whence the expression becomes

$$-\int_{t_1}^{t_2} \frac{dt}{a + bt} = \frac{\int_0^M dm}{H} + \frac{\int_0^\theta d\theta}{L_1}$$

or

$$\frac{1}{b}\,L\left(\frac{a + bt_1}{a + bt_2}\right) = \frac{M}{H} + \frac{\theta}{L_1}$$

In developing the logarithm in series following the increasing powers of

$$\frac{b}{a}$$

and stopping after the term in

$$\frac{b^2}{a_2}$$

we have

$$\frac{1}{a}(t_1 - t_2)\left[1 - \frac{1}{2}\frac{b}{a}(t_2 + t_1)\right] = \frac{P}{II} + \frac{\theta}{L_1}.$$

In grouping the experiments two and two, we shall have as many systems of two equations as of groups of experiments, and as many values of the quantities

$$a \text{ and } \frac{b}{a}$$

that is to say, of a and b.

The following are the results obtained:

Nos. of the Groups.	a	$-\frac{b}{a}$	$-b$
1, ...	95·035	0·0013521	0·1285
2, ...	95·200	0·0013655	0·1300
3, ...	95·285	0·0013749	0·1310
4, ...	95·360	0·0013528	0·1290
5, ...	95·066	0·0013695	0.1302

Interpretation of the Results.—Before showing the manner in which I have interpreted the results obtained, I think there should be briefly recalled the principles of the theory of errors which I have adopted.

When by a succession of measures freed of systematic errors, we have obtained different values of a quantity function of a variable, it is often interesting to represent that quantity by an empirical function of that variable, of the form

$$A + B_x + C_{x^2},$$

for example.

The coëfficients A, B and C are determined in such a manner that the sum of the squares of the residues ε, calculated after the m relations

$$\varepsilon_1 = N_1 - (A + B_{x_1} + C_{x_1^2})$$

$$\varepsilon_2 = N_2 - (A + B_{x_2} + C_{x_2^2})$$

is a minimum (N_1, N_2, etc., being the results of experiments.)

The mean error of a determination is

$$\sqrt{\frac{\Sigma(\varepsilon^2)}{m}}$$

and the probable error is about two-thirds of that, namely,

$$\frac{2}{3}\sqrt{\frac{\Sigma(\varepsilon^2)}{m}}$$

If we have a quantity M, function of several others

$$M = F\,(P, Q, R, \text{etc.}),$$

and if p, q, r represent the mean errors of P, Q, R, the mean error of M will be

$$\sqrt{\left(\frac{dM}{dP}\,p\right)^2 + \left(\frac{dM}{dQ}\,q\right)^2 + \left(\frac{dM}{dR}\,r\right)^2 + etc.}$$

the probable error being still two-thirds of the mean error.

I will now pass in review the different determinations made, giving for each the calculated formulæ and the respective mean errors.

Value of u.—The two values 0·7035 and 0·7025 have been found for the density of ether at 30°; the mean is 0·7030, the mean error being 0·0005.

The value 0·7038 found by Isidore Pierre, is a little but not much greater.

The specific volume

$$u \text{ is } \frac{1}{d} = \frac{1}{0{\cdot}703} = 1{\cdot}422 \text{ cc.}$$

and the mean error.

$$\delta u = \frac{\delta d}{d^2} = 0{\cdot}001$$

The coëfficient of dilatation, which I have found equal to

0·0017524, is intermediate between the following numbers given by different experimenters.

0·0017531 (Is. Pierre).
0·0017668 (Kopp).
0·0017421 (Hirn).

I have taken as the value of u, τ being the excess above 30° of the temperature expressed in degrees,

$$u = 1^{cc}{\cdot}422 + 1{\cdot}422 \times 0{\cdot}00175\,\tau,$$

whence

$$u = 1^{cc}{\cdot}422 + 0{\cdot}00249\,\tau \text{ (mean error 0·001).}$$

Value of $\dfrac{dp}{dt}$

First Method.—I have put

$$p = A + B\tau + C\tau^2,$$

and calculated A, B, C, by the method of least squares with the aid of each of the three groups of measures effected, as previously shown.

I have thus found:

	A. Centimetres.	*B.*	*C.*
First group, ...	63·722	2·3593	0·04
Second group, ...	63·684	2·3599	0·04
Third group, ...	—	2·3587	0·04
Means, ...	—	2·3593	0·04

The mean error on B has been calculated at 0·0005. The values given by Regnault are:

$$A = 63{\cdot}5035 \qquad B = 2{\cdot}3548$$

The difference on the value of B is, as shown, very slight.

Second Method.—In putting

$$\frac{dp}{dt} = B + C'\tau$$

I have found

$$B' = 2{\cdot}3584 \qquad C' = 0{\cdot}0834$$

Calculating the mean error of the determinations, we find

0·0005.

The value of C' is, as it ought to be, twice the value of C.

The value taken for

$$\frac{dp}{dt}$$

is, in centimetres of mercury,

$$\frac{dp}{dt} = 2{\cdot}3584 + 0{\cdot}0834\ \tau$$

or, in grams per square centimetre,

$$\frac{dp}{dt} = 32{\cdot}0648 + 1{\cdot}1359\ \tau \text{ (mean error } 0{\cdot}007).$$

Value of L.—In introducing τ into the formula

$$L = a + bt,$$

we have the following relation

$$L = a' + b\tau \ (a' = a + 30\ b).$$

The values of a' thus determined are:

	a'	b
First group, ...	91·18	— 0·1285
Second group, ...	91·30	— 0·1300
Third group, ...	91·35	— 0·1310
Fourth group, ...	91·49	— 0·1290
Fifth group, ...	91·16	— 0·1302

The calculation made has given for a' and b the values

$$a' = 91{\cdot}29, \qquad b = 0{\cdot}1297,$$

the mean error being 0·12.

The formula I have finally adopted is

$$L = 91{\cdot}29 - 0{\cdot}1297\ \tau. \tag{1}$$

Regnault gives

$$L = 94{\cdot}00 - 0{\cdot}07901\ t - 0.0008514\ t^2,$$

which corresponds for a formula in τ, to

$$L = 91{\cdot}395 - 0{\cdot}13109\ \tau - 0{\cdot}0008514\ \tau^2, \tag{2}$$

regard being had to the mean error 0·12, these two formulæ can be considered as concordant.

Value of $\acute{u}$.—The two methods employed being sufficiently concordant, the results found by the application of each have been employed without distinction of origin for obtaining the value of $\acute{u}$.

I have consequently based the calculation on the results of the first method obtained for the temperatures

28°·4, 30°·0 31°·7, 31°·9,

and on those of the second corresponding to

28°·6, 29°·375, 29°·72, 30°·02, and 31°·50.

The two other results obtained in that last series, the one at 27°·66, the other at 34°·12, should be omitted as too far removed from the temperature of 30°. It would have been necessary to use a formula in τ^3 in order to represent them.

The formula obtained is the following:

$$u' = 400{\cdot}42 - 15{\cdot}7394\,\tau + 0{\cdot}539\,\tau^2$$

The following table shows in comparison the numbers resulting from experiment and from calculation. The numbers in heavy type were obtained by the first method.

Temperature.	*Found.*	*Calculated.*	*Difference.*
28·40	**426·20**	426·08	+ **0·1**
28·60	423·90	423·51	+ 0·4
29·375	410·40	410·48	— 0·1
22·72	405·10	404·87	+ 0·2
30·00	**400·00**	400·42	— **0·4**
30·02	399 90	400·11	— 0·2
31·50	377·20	377·02	+ 0·2
31·70	**375·10**	375·22	— **0·1**
31·90	**373·00**	372·56	+ **0·4**

The mean error is 0·28.

Value of E.—There only remains to introduce into the formula

$$E = \frac{T\,(u' - u)\,\frac{dp}{dt}}{L}$$

the preceding results in order to obtain the value of E, which will be expressed in grams-centimetres, corresponding consequently to a small calorie. If, in the preceding formulæ, we make

$$\tau = o$$

$$E = \frac{303\,(400{\cdot}42 - 1{\cdot}42)\,32{\cdot}0648}{91{\cdot}29} = 42463$$

The mean error on the value of E is about 0·5: the probable error will consequently be 0·34.

If, in the relation there be introduced the formulæ themselves which represent

$$u,\ u',\ \frac{dp}{dt} \text{ and } L$$

in function of τ, there is obtained for representing E, a function of τ

$$E = \frac{(303 + \tau)(400{\cdot}42 - 15{\cdot}7394\,\tau + 0{\cdot}539\,\tau^2 - 1{\cdot}42 - 0{\cdot}0025\,\tau)(32{\cdot}0648 + 1{\cdot}1359\,\tau)}{91{\cdot}29 - 0{\cdot}1297\,\tau}$$

I have calculated the values of that function for several values of τ, and found them to vary very slowly.

Value of τ	*Value of E.*
— 1·0	42429
— 0·2	42458
— 0·1	42461
0·0	42463
+ 0·1	42467
+ 0·2	42470
+ 1·0	42493

This is, I believe, an important verification of the final result. It is evident that there cannot be found for E a quantity independent of τ, but the variation is very slight here, for it is sensibly represented by

$$E = 42463 + 30\,\tau.$$

From $\tau = -0{\cdot}2$ to $\tau = 0{\cdot}2$ it is only 12, while the probable error of a determination is 34.

Finally, the value of the mechanical equivalent of heat found in the last place, very near the numbers deduced from the experiments on water, previously given, is in kilogrammetres

424·63

with a probable error of 0·34.

Seen and approved:
Paris, the 7th October, 1887.
E. Hébert,
Dean of the Faculty of Sciences.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, January 19, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 19, 1892.

Dr. W. H. WAHL, President, in the chair.

The election of officers, which was postponed from the December meeting, was first taken up, and on motion the Secretary was directed to cast the vote of the Section for all the nominees.

Mr. Chas. S. Boyer read a paper giving the results of a number of analyses made by him of egg yolk. It was referred for publication in the *Journal.*

Mr. H. Pemberton, Jr., followed with two communications, one on gas analysis, including the description of a new form of gas measuring apparatus, which simplified the reduction of volumes to the standard conditions of temperature and pressure. The second paper was a description of a rapid method for the determination of carbonic acid gas. Both were referred for publication in the *Journal.*

Dr. Wahl then presented a paper presenting a new interpretation of the chemical reactions which take place in the operation by which aluminium is deposited in the electrolytic process of manufacture. The paper included a complete description of the process as it is at present carried out, and was followed by the explanation in detail of the views entertained by the author on this interesting subject. Dr. Wahl also exhibited a number of aluminium articles recently turned out by the Pittsburgh Reduction Company. The paper was referred for publication, and after some discussion upon it, and an inspection of the exhibit, the Section adjourned.

WM. C. DAY, *Secretary.*

THE SPECIFIC HEAT OF ALUMINIUM.

By J. W. RICHARDS, Lehigh University.

[*Read at the stated meeting of the Chemical Section, held December 15, 1891.*]

The determinations of the specific heat of aluminium are but few in number, and yet vary widely.

As soon as Sainte-Claire Deville had obtained a button of aluminium, in 1855, his friend Regnault importuned him for a specimen with which to determine its specific heat, and although Deville knew that the metal he had made was far from pure, yet he yielded to Regnault's request and furnished him with three small pieces, which analyzed:

Silicon,	2·87
Iron,	2·40
Copper,	6·38
Lead,	traces
Aluminium,	88·35

Regnault determined the mean specific heat of this metal between 25° and 97° to be 0·2056. He attempted to calculate approximately the specific heat of pure aluminium by allowing for the impurities present. In doing this he assumed the specific heat of silicon to be 0·1425, it not having been then determined, and his calculation gave him 0·2181 as the number for pure aluminium. Had he, however, used what we now know to be the specific heat of silicon, 0·21, he would have calculated 0·2200 as the specific heat of pure aluminium between 25° and 97°.

A year later Regnault obtained aluminium about 97 per cent. pure. He obtained for this, between 14° and 97°, 0·2122. Allowing for the impurities present, he calculated 0·2143 as the probable number for pure aluminium.

It may be remarked in passing, as a curious fact, that Regnault treats these mean values as if they were invariable constants, independent of the range of temperature through which they were determined.

Following Regnault came Kopp, who in 1863 made determinations with ordinary Parisian aluminium. He obtained 0·2020 as the mean value between 20° and 52°. However, no analysis is given of the metal used, and from a consideration of the way in which Kopp experimented, and the degree of accuracy which was possible in his experiments, it is evident that his results are of very little value. For instance, four determinations gave him

0·1970
0·2000
0·2070
0·2020

from which he simply deduces 0·2020 as an average value.

In 1882, Professor Mallet made some absolutely pure aluminium for his researches on the atomic weight, and he determined its mean specific heat between 0° and 100°, by means of a Bunsen ice calorimeter, to be 0·2253. Since no impurity was present in the metal, this determination is free from one of the sources of error of the previous ones.

More recently, Naccari, the noted Italian physicist, states that he obtains for the true specific heat of aluminium at various temperatures the following values:

18°	50°	100°	200°	300°
0·2135	0·2164	0·2211	0·2306	0·2401

It will be noticed that these values indicate that the specific heat increases 0·0095 per 100°, and lead to the formulæ:

$$S = 0{\cdot}2116 + {\cdot}000095\, t$$
$$Sm = 0{\cdot}2116 + {\cdot}0000475\, (t_1 + t_2)$$

in which 0·2116 is the true specific heat at 0°. The mean between 0° and 100° would be 0·2164, comparing well with Regnault's results, but much lower than Mallet's. It is not stated what was the purity of the metal used by Naccari.

The question which the writer set out to solve presented itself to him in this way: Who is nearest the truth, Regnault and Naccari, or Mallet?

I obtained some aluminium made by the Hall process, which analyzed:

Silicon,	0·07
Iron,	trace
Aluminium,	99·93

Since the atomic weight of silicon is almost identical with that of aluminium, it was felt safe to neglect the influence of the 0·07 per cent. present.

Three methods of procedure were used. First, a large weight of aluminium (100–200 grms.) was put into an empty calorimeter, whose water equivalent had been accurately determined by experiment, and allowed to stand several hours. When the temperature was nearly constant, a known weight of water at a higher temperature was run in, and the total loss of heat calculated from the observations. This method gave mean specific heats between about 16° and 22°. Secondly, the aluminium was suspended in steam and dropped into the water in a calorimeter. This gave values from 20° to 100°. Thirdly, two exactly similar calorimeters were used. The aluminium and a platinum ball weighing fifty-two grammes were placed on a platinum support and heated together either in an air bath to 120°, or in a small furnace up to 400°, 500° and 600°. The platinum ball was dropped into one calorimeter and the lump of aluminium into another. From the heat given out by the platinum its temperature was calculated, and assuming that the aluminium had been at the same temperature, I had the data for calculating its mean specific heat.

The third method gave the most concordant results. The first method was used for such a small range of temperature that the experimental errors were large. The second method was defective in default of suitable apparatus to secure the instant transfer of the metal from the steam into the calorimeter. The third method had the advantage, that since the platinum and aluminium were taken out of the furnace together and were dropped almost simultaneously into the calorimeters, it could fairly be assumed that they would cool about the same amount in the two or three seconds during which they were exposed to the air.

The writer has made two experiments by the first method, five by the second and sixteen by the third. Selecting those experiments, which were experimentally the nearest to perfect ones, and correlating the data by the method of least squares, the following formulæ were arrived at:

$$\mathrm{Sm} = 0{\cdot}2220 + 0{\cdot}00005\,(t_1 + t_2)$$
$$\mathrm{S} = 0{\cdot}2220 + 0{\cdot}0001\,t$$

in which 0·2220 is the true specific heat at 0° C.

From these formulæ the following values will be shown:

Temperature.	*True Specific Heat.*	*Range of Temperature.*	*Mean Specific Heat.*
0°	0·2220	0° — 100°	0·2270
20°	0·2240		
100°	0·2320		
		0° — 625° (melting point)	0·2533
625° (melting point)	0·2845		
		Total caloric capacity to the melting point,	. . 158·3

It is seen that the author's results confirm Mallet's determination, as far as the true specific heat is concerned, and agree closely with Naccari's observation of its rate of increase with the temperature.

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, January 5, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 5, 1892.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, thirty-six members and visitors.

The minutes of the previous meeting were read and approved.

One nomination to membership was referred to the Committee on Admissions. The committee reported three elections since last meeting.

Mr. A. L. Church's resignation of membership was presented and accepted.

Mr. H. S. Hering gave a description of some types of recording volt- and ammeters, and suggested some new modifications.

Mr. W. S. Aldrich continued his remarks upon electro-magnetic machinery, with lantern illustrations.

Prof. Houston read a paper on "An Early Conception of Magnetic Field." Referred for publication.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

THE ELECTRIC RAILWAY AT BUDA PESTH.

BY H. W. BARTOL.

[*Abstract of paper read at the stated meeting, held December 1, 1891.*]

Ever since electricity has become not only a possibility for traction purposes, but has in fact come largely into use for that purpose, efforts have been made to arrive at some satisfactory system for use in cities whereby the overhead wire could be dispensed with.

With the above intention, extensive experiments have been made with storage batteries and some few attempts made to supply the necessary current through a conduit, having an open slot somewhat similar to that used by the cable companies, a notable instance of which was the short piece of line laid in the city of Boston a few years since.

Repeated trials have shown that up to the present time there is no storage battery which can be used to advantage, and the battery experiment having failed, many had concluded that we must adopt the trolley system or wait for further developments in electrical propulsion.

There have been several patents taken out for supplying the current through an underground conduit, with an arrangement whereby only a small portion of the conductor is charged at a time, the object being to prevent (what was supposed to be a very serious loss) leakage, but while experiments were being made in that direction in this country, actual practice on the other side of the ocean has shown that this is a danger more imaginary than real, and while we have been seeking to overcome this, Messrs. Siemens & Halske, of Berlin, have built and have had in operation for over two years in Buda Pesth, a road which supplies the current through a conduit, and which it is now my intention to briefly describe.

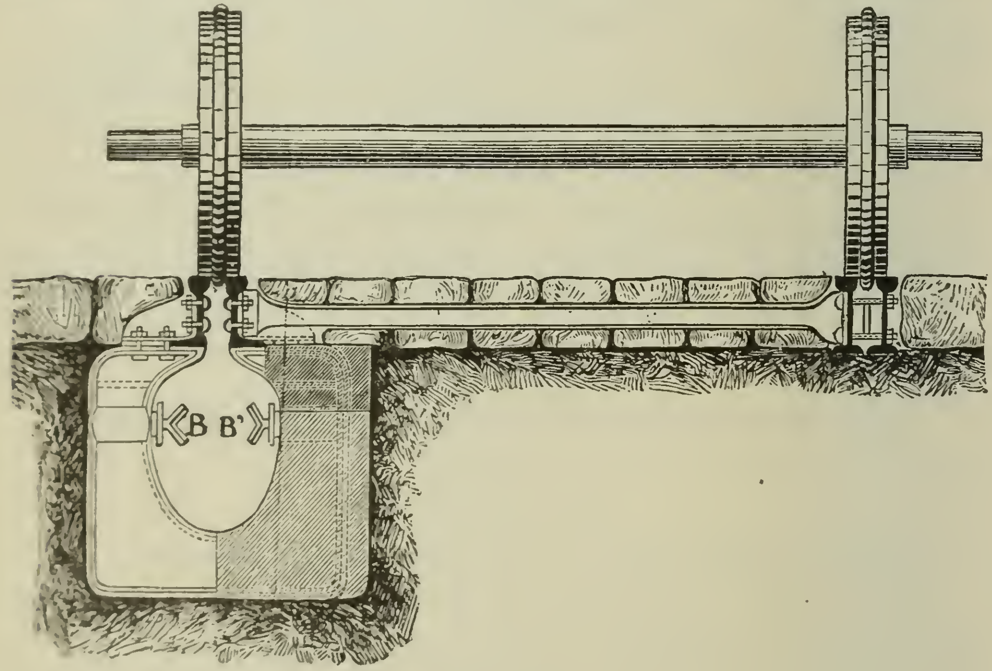


FIG. 1.

By referring to *Fig. 1* you will see a conduit shown on the left, the slot being used as a groove for a flange of one of the wheels; *B* and *B′* are the conductors which supply the necessary current for driving the dynamo on the car. This conductor is made of angle iron properly insulated, and in it runs a trolley which makes contact with the two sides, viz: at *B* the current is received and at *B′* it is returned to the power station.

Fig. 2 represents a number of the iron frames in place and shows how the arrangements for switching are made.

Fig. 3 shows a truck and motor, in which it will be noticed they use a chain instead of gearing for reducing the speed and which it is claimed does away with a great deal of the noise.

The actual results obtained in Buda Pesth and the cost of building the road there are as follows: cost of road-bed, conduit, conductor, repaving, etc., $20,000 a mile. The voltage employed is 300, the ampères used in running the car after it is started, twenty-three; to start the car, however, when fully loaded, requires about eighty ampères. The weight of the car empty is about four and one-half tons, and its carrying capacity when full is forty people.

The heaviest grade in Buda Pesth is one and six-tenths per cent., but experiments on a four per cent. grade show that it requires an average of thirty-eight instead of twenty-three ampères to obtain the same speed.

We now come to some of the more practical considerations, namely: Is the road a success, and is the leakage such an item as to figure materially in the cost of operation? To the first of these questions the answer is unequivocally, Yes; to the second the answer is, that in dry weather the leakage is practically *nil*, and in wet weather on a line thirteen miles long it does not exceed three per cent., and in addition to this, is the fact that the friction of moving the car is so much less in wet weather than in dry that it actually requires less power at the power station notwithstanding the three per cent. leakage.

As the conduit is connected with the sewer at many points, no trouble is experienced from its filling with water, nor have they encountered any trouble in keeping the line free from snow, although the climate in Buda Pesth is fully as cold as that of Philadelphia.

The contact which takes the current from the conductor is a sliding one and of iron and the conduit between the iron frames is made of cement.

The speed allowed in Buda Pesth is ten miles an hour and in the suburbs eleven and one-half, which speed they

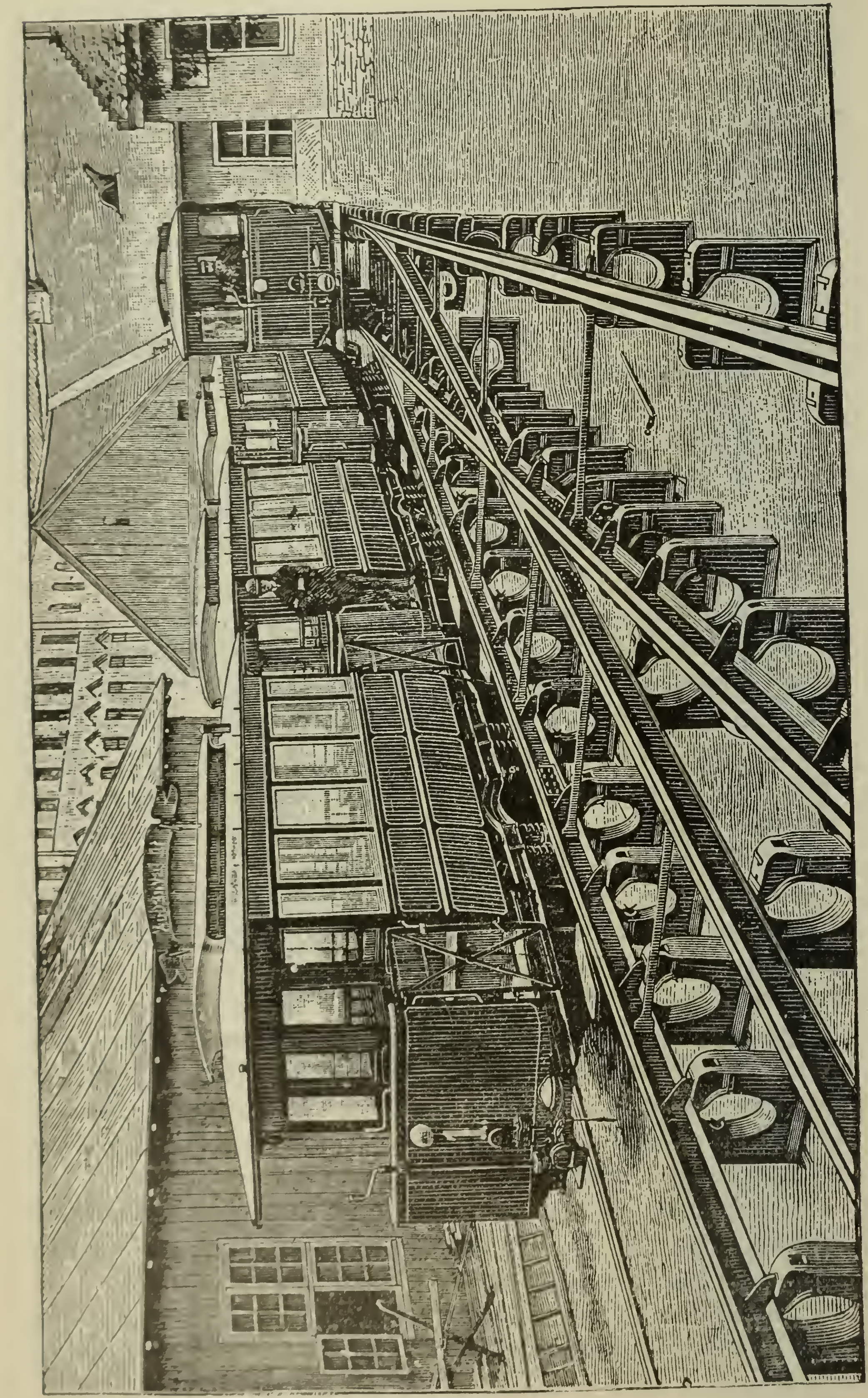


Fig. 2.

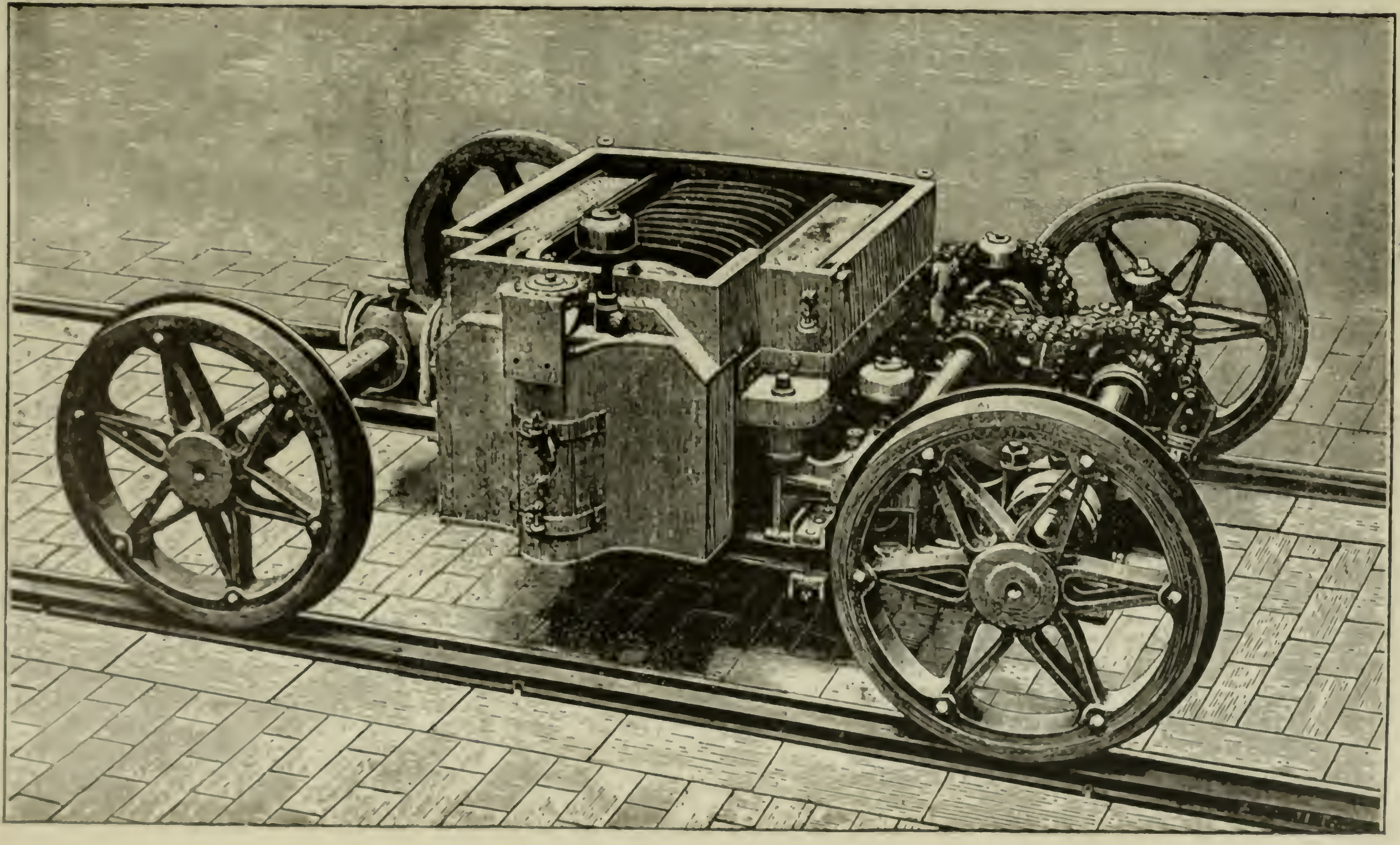


Fig. 3.

find no trouble in maintaining. The operating expenses of the company are lower than those of nearly every company using the trolley system in this country, and the company is paying dividends.

In conclusion, I might add that this system is soon to be given a practical test in this country, as a prominent railroad syndicate has undertaken to build six miles, and I am sure the public will agree with me in hoping it will be a success and a step in the direction of securing what all want, namely, a satisfactory system of rapid transit without the disadvantage of the overhead trolley or the great expense of the cable.

NOTES ON ELECTRO-MAGNETIC MACHINERY.

[FIRST PAPER.]

By Wm. S. Aldrich, M.E.,
Associate in Mechanical Engineering, Johns Hopkins University.

[*Read at the meeting of the Electrical Section held December 1, 1891.*]

The terms Machinery, Machines, Mechanisms are scarcely synonymous, though often so used. Early writers on the subject, among which the names of Monge, Carnot and Lanz are prominent, speak of mechanisms as means for altering or changing the direction of motion; such as the conversion of motion from continuous circular to reciprocating rectilinear motion. Ampère defined those mechanisms to be pure, which consisted entirely of rigid bodies, limiting, as it were, the definition to the means by which the motion was produced or transferred; and he defines a machine to be "an instrument by the help of which the direction and velocity of a given motion can be altered." Willis, in his *Principles of Mechanism*, follows closely, at first, with a classification based on comparative motion, subordinating the means and modes of communication by which these motions were obtained; but, later, making the mode of communication primary, and the comparative motion secondary in his classification of the elementary combinations of pure mechanism. Rankine, in his *Machinery and Millwork*, adheres to Willis' later classification, but includes hydraulic connection as having a legitimate place among the means for the communication of motion in mechanisms. This marks a definite advance, for the means employed to communicate or transmit motion may be quite different, but the kinematic question remains the same—which is that of pure motion.

The Idea of the Kinematic Chain was brought out by Reuleaux, in his work on the *Kinematics of Machinery*, as the next step in the development of the science of machinery. He thus defines a mechanism to be "a closed kinematic chain, which is compound or simple, and consists of pairs of elements; these carry the envelopes for the motion which the parts in contact must be given, and by these envelopes all other motions are prevented." The constrainment of motion now becomes a fundamental condition for every mechanism, and subordinates the mere question of directional—relation or of velocity-ratio, as determined by the comparative motion of any two points of the mechanism. A machine is a mechanism so operated as to do work, and is stated by Reuleaux to be "a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work, accompanied by certain definite motions."

The Electro-magnetic Connection of Moving Parts, in a mechanism or a machine, followed naturally upon the inclusion of hydraulic and pneumatic modes of communicating motion. For development in any line becomes apparent when a general identity is to be seen through many special varieties. And, however varied may be the mechanical movements of any machinery, or however simple the relative motions amidst the complicated mechanism, the ultimate analysis shows simple well-known motions, obtained by well-known pairs of elements and kinematic chains, whether such chains are composed entirely of rigid connecting elements, or of hydraulic, pneumatic, or electro-magnetic connection. Seeing, therefore, that the time was ripe for another mode of connection in mechanism, and which should include the electro-magnetic forces of nature as among "the mechanical forces of nature [that] can be compelled to do work, accompanied by certain definite motions," Sylvanus P. Thompson has given us the term "Electro-magnetic Mechanisms," and considered them somewhat at length in connection with his work on *The Electro-magnet.* It is my purpose in these papers to speak of these mechanisms when put to do work, as electro-magnetic machines; and the general term, electro-magnetic machinery, will include such mechanisms as may be more or less useful in the conversion of motion under constrainment, and such machines as may be useful in the direct transmission of energy—by electro-magnetic means.

The Medium for the Transmission of Energy may likewise serve, as it often does, as the means for communicating motion; and, when energy is transmitted along with the conversion or transfer of motion in any mechanism, that mechanism becomes a machine. Any medium, therefore, which is of such a nature as to admit of its being made a part or link in the mechanism of the energy cycle, will serve in almost all cases, equally well for the transmission of energy or of motion; provided, that notwithstanding the deformations to which it may be subjected, the medium is capable of returning to its original condition. Some mediums or links are practically incompressible and inextensible, within the usual limits of the transmitted energy; such as, iron rods, retaining their form throughout; and a water connection, which retains its volume while altering its volume-form. Other mediums admit of practical extension, but are of little use in compression; such as, belts, wire ropes, and like flectional elements used as wrapping connectors in mechanism. Compressed air, springs, and like flectional elements admit of practical extension and compression, and are of more or less value in the transmission of energy; but, of little use as elements or links of a kinematic chain, for constrained motion. In all of these energy is transferred by and through matter in some one of its many forms—matter which follows the laws of the continuity of matter and of space, while entering as a medium in the continuity of energy.

Systems for the Transmission of Energy have therefore become quite definitely established, for long or short distances, and have taken the following broad lines of development:

(1) Mechanical transmission, by belts, wire ropes, and other wrapping connectors for long or short distances; and, by gear-wheels, links, screws, cams, ratchets, and like forms, for more immediate and direct transmission.

(2) Hydraulic transmission, with pumps, accumulators, connections, motors and presses, more or less varied in form for utilizing water-pressure.

(3) Pneumatic transmission, with the compressors and apparatus especially adapted to that medium.

(4) Electric transmission, with dynamos, line connections, regulators and motors, and chiefly used in long-distance transmission.

It is proposed to add:

(5) Electro-magnetic transmission,* in which the dynamo and motor, as generator and receiver, or as driver and follower, shall be in the same magnetic circuit; or, in which the magnetic circuit shall be used for direct and immediate distribution of energy for very short-distance transmission, in much the same way as the electric circuit is even now used for long-distance transmission.

The Ether as the Medium for the Transfer of Energy, by electric or electro-magnetic means, has been found to possess many striking analogies to other and better known mediums. By the modern theory of electricity, the electric energy is supposed to be concentrated in the ether surrounding the conductor, or other core of disturbance, and that a transfer of the ether energy takes place whenever electric energy is being transmitted from point to point. However great may be the contrast between the mechanical, hydraulic and pneumatic transmission of energy and the *etheric* transmission, it remains a fact that energy may be transmitted by all of these means, with varying degrees of efficiency, and accompanied, if desired, by definite conversion of motion. The former three require some material connecting-link between driver and follower—some kind of contact of elements, or some pairing of surfaces—while the etheric transmission requires no such material contact or pairing; indeed, such contact may kinematically lock the whole mechanism, as an armature, in contact with its core in some special forms of this type of electro-magnetic mechanisms. The ether medium allows of the transmission of constant or varying forces, as now transmitted by more material modes of connection; and, with the peculiarities of comparative and constrained motion accompanying such energy transmission. By the displacement theory, electricity seems to act as an incompressible fluid. By the researches of Hertz, the ether appears to be possessed of some peculiar mechanical properties, such as inertia, and stress and strain manifestations. We have even come to conceive of the mechanism of the ether medium, and to picture some of the peculiar manifestations of the ether mechanism as analogous to gear-wheel mechanisms.

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* Paper read before the Electric Club of the Johns Hopkins University, November 9, 1891, on "Notes on Electro-magnetic Transmission of Energy."

The Kinematic Conception of the Ether Mechanism, in combination with the peculiar mechanical properties apparently possessed by the ether medium—however far from being a true conception, may serve the passing moment till a better working hypothesis is presented. We know that the ether energy of the electric current and of the magnetic circuit, moves at right angles (normal) to the direction of the current or the axis of the magnet; also, while the instantaneous direction of motion of a point in the pitch circle of a gear-wheel is tangential to its path, the energy is transmitted radially or normal. These peculiar gear-wheel properties of the kinematics of the ether mechanism, like all good illustrations, leave us in doubt as to many points; especially, as to whether the ether gear-wheels are more or less flexibly mounted, as on springs, but with apparently limited or even fixed distances between centres. Perhaps Oliver J. Lodge may yet point out to us whether these gear-wheels, as elements in the ether kinematic chain of mechanism (speaking in the phraseology of Reuleaux) are pair-closed, force-closed, or chain-closed. That is, whether they mesh with each other by reason of some peculiarity of their paired connection or characteristic conformation of their toothed outline; or, are by some force kept in geared connection, akin, perhaps, to the manifest tendency of the magnetic circuit to complete or perfect itself—to enclose the greatest possible number of lines of force in following the path of least resistance, and yet to remain as undeformed as possible in the presence of opposing magnetic forces—a kind of electro-magnetic force-closure; or, perhaps, these ether gear-wheels may have their centres connected by a link or chain device, not yet made clear. And the time may come when the kinematics of this hypothetical mechanism of the ether may be as definitely studied as its mechanics; and, the paths of its moving elements as clearly laid down as now in the case of link-work, cams, gearing, etc. The ether medium has already been made to yield some of its many possibilities in the applications of electricity and magnetism; and, its peculiar characteristics show it to be capable of the widest range of usefulness in the transmission of energy and of motion, for a long or short distance, and by immediate and direct, or by indirect means. And the beautiful electro-magnetic induction experiments of Elihu Thomson, the high frequency alternating-current effects obtained by Tesla, and the researches of Crookes in high vacua—give grounds for hoping that the day is near at hand when these invisible forces will be clearly seen and understood by the things that are made.

Electric Transmission of Energy is shown in simple ideal form in *Fig. 1* for long distances; in *Fig. 2* for short distances. In either case, but especially the latter, we may suppose the axes of the two armatures to be placed parallel, or in any given oblique position to each other, being then similar to transmission by belts and wire ropes. The speeds of the two shafts may be maintained constant under changes of load, or varied at will; and the rotations may be in the same or opposite directions, and, reversible at will. The current used may be direct or alternating. Power applied to drive one as a dynamo, will drive the other as a motor;

while if power be applied to both, the output will be current in the external circuit, as given by two dynamos coupled for any given output. Current supplied to drive one as a motor will serve to drive the other as a dynamo, giving an electric-motor-driven dynamo as a transformer, if the two shafts are in any way coupled or geared; while, if current be supplied to both, the output is power from each machine acting as a motor. More than two machines are often used, and sometimes one dynamo operates several motors in the same electric circuit, but with individual magnetic circuits. In the figures from *1* to *12*, inclusive, *P*, *Q*, *R*, represent armatures and armatured shafts, and *A*, *B*, *C*, fields and field coils.

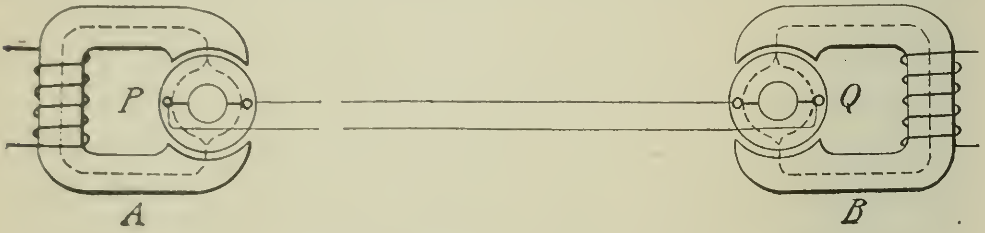

FIG. 1.—Long-distance electric transmission of energy.

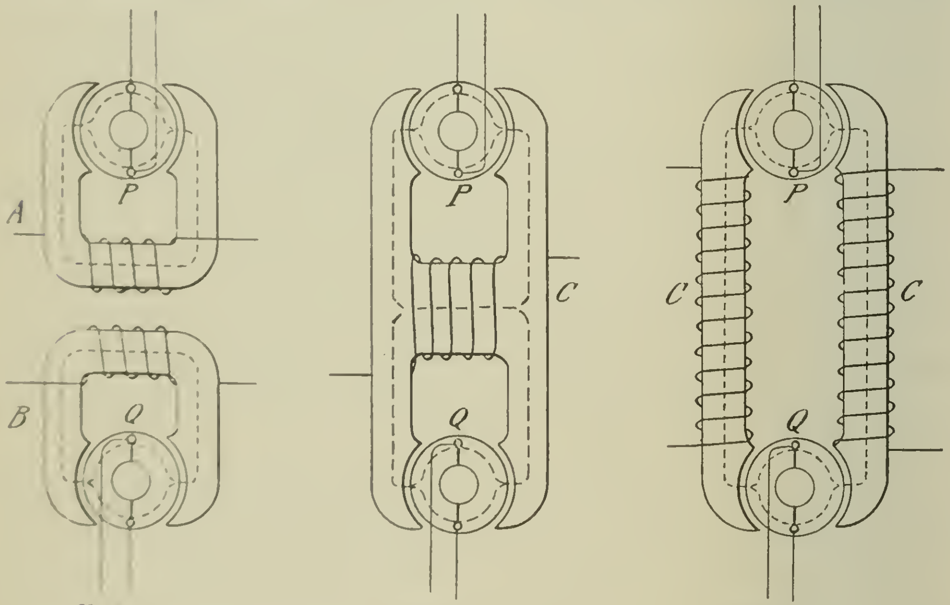

FIG. 2. FIG. 3. FIG. 4.

Short-distance electric and electro-magnetic transmission of energy.

Electro-magnetic Transmission of Energy is understood to mean that combination for the transmission of energy in which all the armatures are in the same magnetic circuit.

(*a*) One or more of these armatures, as dynamos, may be utilized to generate current, which may be supplied to the remaining armatures, as motors, in the same magnetic circuit; or, (*b*) all the armatures may be run as motors by an external source of supply of current; or, (*c*) all the armatures may be run as dynamos by an external source of power. *Figs. 3, 4, 5, 6, 7* and *8* show such combinations of two armatures in the same magnetic circuit, or branches of the same. (*a*) If armature *P* is driven by power, as a dynamo, the current supplied to armature *Q* will drive it as a motor; or, (*b*) if current is supplied to both armatures *P* and *Q*, they will run as motors; or, (*c*) if power is applied to both armatures, current will be generated in the external circuit. This last combination is similar to a separate-circuit self-exciting dynamo (type of *Fig. 4*), brought out by Ladd, March 14, 1867, which had two shuttle-wound armatures—a small one to excite the common field magnet, and a large one to supply currents for electric lighting. We may also arrange any one of the forms shown (*Fig. 2*, for

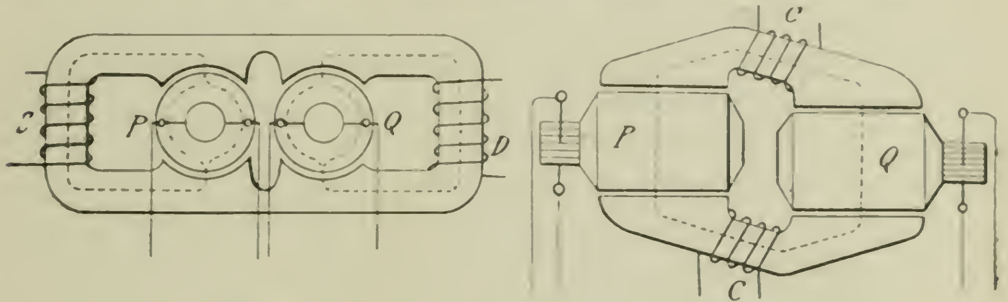

FIG. 5. FIG. 6.

Dynamotors for parallel shafts in close proximity.

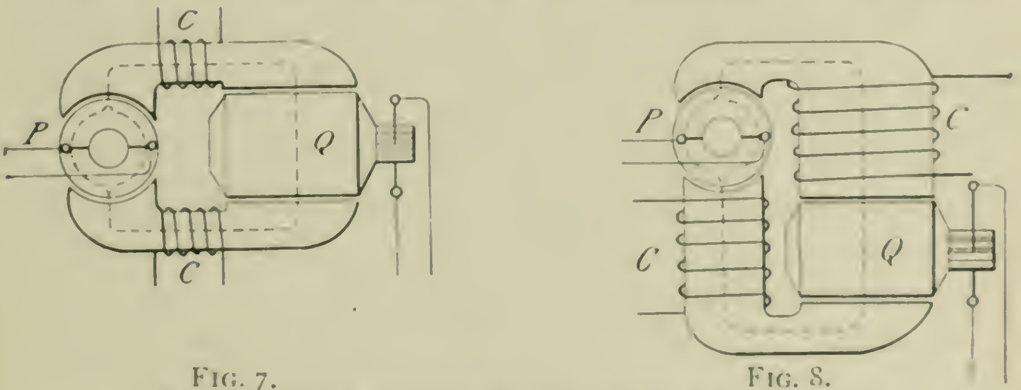

FIG. 7. FIG. 8.

Dynamotors for intersecting and non-intersecting axes.

instance), as a dynamo-transformer, by supplying current to armature *P*, acting then as a motor, and gearing or otherwise coupling the shafts *P* and *Q*, so that armature *Q* acts as a dynamo, giving a transformed current within any given range.

Dynamotors for Electro-magnetic Transmission of Energy are combinations of armatures in the same magnetic circuit, as illustrated in *Figs. 3, 4, 5, 6, 7* and *8*, which show two armatures in the same magnetic circuit, as dynamo and motor. A dynamo-motor combination, in the same electric circuit, but with *individual* magnetic circuits, as *Fig. 2*, is really a transformer of mechanical energy; while a motor-dynamo combination, similarly arranged, is a transformer of electrical energy. The dynamotor is also a dynamo-motor combination, in the same electric and the *same* magnetic circuits, *Figs. 3, 4, 5, 6, 7* and *8*, and as such is also a transformer of mechanical energy; but it may also be used as a transformer of electrical energy. These dynamotors allow of a constant or variable velocity-ratio being electro-magnetically transmitted between two shafts arranged in any way with inclose proximity, for the immediate and direct transmission of energy. The direction of rotation as well as the velocity-ratio may be varied at will. Direct or alternating currents may be used, but preferably the latter, and very probably some form of the so-called rotary current. The dynamotor may be an independent machine, with no external circuit connections, or it may be more or less dependent upon some external source of current supply, either for regulation of velocity-ratio, or of its operations as an energy transformer.

Mechanical Equivalents of Dynamotors are those mechanical means for the transmission of energy and motion, equivalent, from the standpoint of kinematics, to the electro-magnetic means employed in the dynamotor. Thus *Figs. 3* and *4*, show dynamotors for parallel shafts, in ordinary proximity, and have their mechanical equivalents in belts, spur gearing and like means for the transfer of circular motion between parallel shafts. *Figs. 5* and *6* show dynamotor forms for parallel shafts very close together, as in Oldham's coupling. Shafts intersecting at an angle, such as in bevel gearing, universal joints, Hooke's joint, etc., are mechanically equivalent to the form of *Fig. 7*. Screw wheels, worm wheels, and skew-bevel wheels, are mechanically equivalent to the form of *Fig. 8*, for transmission between non-intersecting axes.

Magnetic Circuits in Parallel and in Series admit of a variety of ways of grouping two or more armatures in electro-magnetic machinery. *Fig. 9* shows the simple ideal grouping in parallel or magnetic shunt, with one energizing coil. The ends of the field, at armature *R* may be closed around, and another coil put in, acting in conjunction with the coil *C*. And with or without this additional coil, separate auxiliary energizing coils, acting in the way of feeders, may be placed between armatures *P* and *Q*, and *Q* and *R*. The simple magnetic shunts, to which Sylvanus P. Thompson refers* may develop into useful industrial applications, such as multiple drills, operated by spindles on armatures arranged in parallel magnetic circuit. Other forms of branch magnetic circuits are shown in *Figs. 3* and *5*. The simple ideal grouping of armatures in series in the magnetic circuit is shown in *Fig. 10*, with one energizing coil. As before, auxiliary energizing coils may be placed at the other end, or between the armatures *P* and *Q*, and *R* and *S*, but these coils do not here act as feeders as they did before in the parallel arrangement, but rather as separated parts of one large coil controlling the one magnetic circuit. This

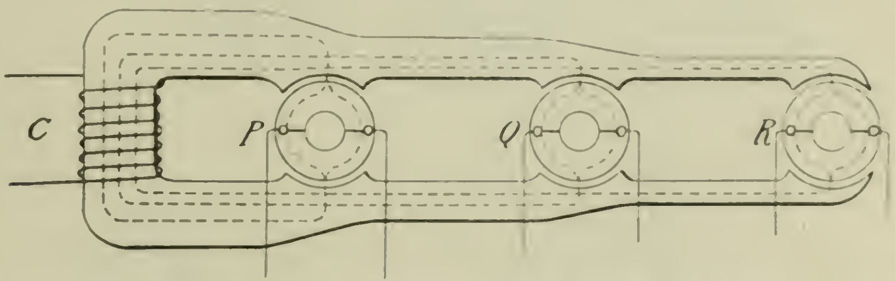

FIG. 9.—Simple ideal grouping of armatures in magnetic shunt, or parallel.

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* "On a Property of Magnetic Shunts," communicated to the Physical Society, April 17, 1891. See *The Electrician* (London). Vol xxvi. April 24, 1891, p. 764.

may be clearly seen by referring to the field coils in *Figs. 4, 6, 7* and *8*, which show the arrangement of two coils in series for one magnetic circuit.

The Electro-magnetic Kinematic Chain may be developed by reference to *Figs. 11* and *12*. Multipolar types are preferably here used. If the arm *L*, connecting the two fields in *Fig. 11*, be *fixed*, the combination may be used as a dynamotor. And by driving armature *Q* as a dynamo, by power, or by a motor secured to the arm *L*, armature *P* will operate as a motor, turning at a certain definite and predetermined speed with respect to *Q*. Should the armature *P* be slowed down by a *fixed* brake or clutching device, and the armature *Q* rotated as before, there will be a rotation given to the field C_1 of *P*, in the *opposite* direction to which the armature *P* is turning, in order that the lines of force across *P* may continue to be cut at the same rate as before; that is, when the field was fixed and the armature was free to revolve. If armature *P* be wholly stopped, its field C_1 will turn around, carrying the arm *L* and its appurtenances, at the same speed at which the armature was formerly turning, but in the opposite direction. If, on the other hand, the speed of the armature *P* be increased, by applying external power, then, to cut the lines of force at the designed rate, the field C_1 of *P*, and so the arm *L*, will have to turn around in the *same* direction as the armature *P*. The armature and its field form an electro-magnetic turning pair of elements; in

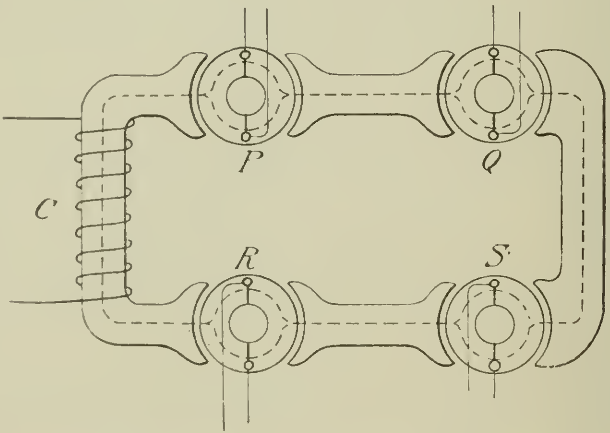

FIG. 10.—Simple ideal grouping of armatures in series, in the magnetic circuit.

the first case above, acting as a motor-turning pair, and in the second case as a dynamo-turning pair of electro-magnetic elements. The placing of two armatures, P and Q, in the same magnetic circuit makes it an electro-magnetic connecting link between them; while, if placed simply in the same electric circuit, they form a combination of elements electrically linked. The electro-magnetic chain is then built up of electro-magnetic links, which connect electro-magnetic pairs of elements. Two or more armatures may therefore be electro-magnetically arranged in series or parallel, or any of the usual modifications and combinations of these groupings. And, from the kinematic standpoint, two or more armatures, with their fields, may be kinematically arranged as an electro-magnetic kinematic chain; the mechanical equivalents of this combination may be seen in belt kinematic chains, wheel-kinematic chains, and crank (linkage) kinematic chains. In general, then, an electro-magnetic kinematic chain may be considered as a combination of electro-magnetic connecting links, so connecting pairs of electro-magnetic elements, that all parts of the chain have determinate motions; such motions being determined by the form of the elements carried by the links, and independent of the application of external force when considered merely as a change in position. *Fig. 12* shows a simple ideal electro-magnetic chain of three links. Whether the armature P is held fixed, or is rotated, certain definite motions may be obtained from the armatures Q and R, in either case. Fix-

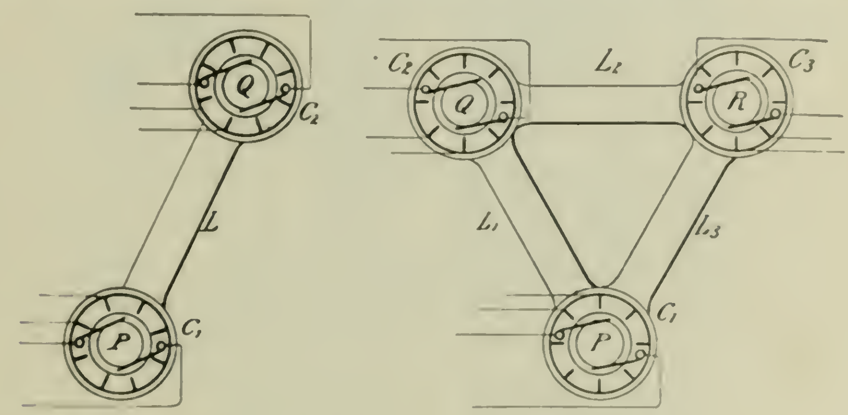

FIG. 11. FIG. 12.

Elements of an electro-magnetic kinematic chain.

ing the centres of armatures Q and R (the same as fixing the rigid connecting link between P and Q, of *Fig. 11*) would lock this three-link chain, so far as any motion of the centre of P, in space, would be concerned, and the armature P would then revolve as about a fixed centre. Kinematic chains of four or more electro-magnetic links admit of a greater variety of relative and constrained motions; and, as in any case, become convertible into a mechanism by fixing one link. The extreme flexibility of the electro-magnetic connection admits of many combinations of the simple electro-magnetic pairs for producing rotation, translation or helical motion.

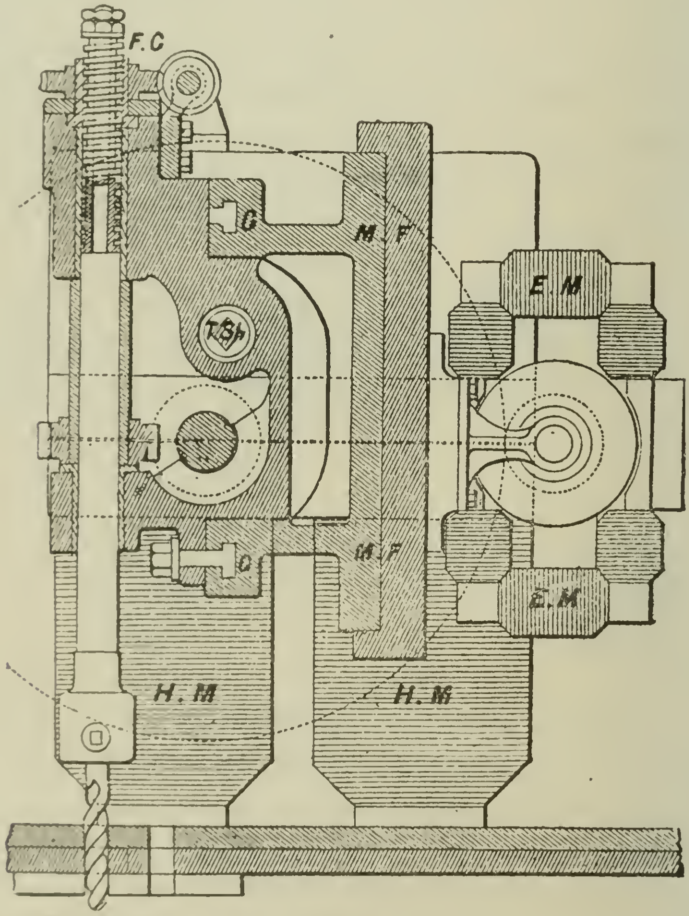

FIG. 13.—The Rowan electric drill with electro-magnetic clamp.

Some Industrial Applications of Electro-magnetic Machinery have been taken from among the many drills operated directly or indirectly by these means. Drilling operations admit of peculiarly compact and portable machines, and ready adaptation of either rotary or reciprocating motions produced and controlled by electro-magnetic means.

The Rowan Electric Drilling Machine, with an electro-magnetic clamping device, is shown in *Fig. 13*.* The main frame, *M F*, is easily placed in position, and electro-magnetically clamped by the holding-down magnets *H M*, to the iron or steel plates to be drilled. The drill is then operated through the usual mechanism for increasing or decreasing the speed, from an electric motor, *E M*, mounted on the main frame *M F*. The feed is by hand, through the feed-gear *F G*. The drill can be moved over the work, along the guides, *G*, *G*, by the transverse shaft, *T Sh*. The Willet's portable electric drill cuts holes two and three-eighths inches diameter through two and one-half inch steel armor-plates, in position on deck, in twenty-one minutes. This work formerly required two men, working a half-day each.

The Van Depoele Reciprocating Electro-magnetic Mining Drill is a good example of the direct application of a controlled reciprocating movement. The length of stroke is about five and one-half inches, and at every stroke the drill turns automatically one-eighth of a revolution about its axis, so that the drilled hole is truly cylindrical. The forward advance is made by a feeding screw operated by hand. About two horse-power is absorbed in drilling holes from one and one-half inch to two inches diameter. In experiments at Frankfort, 1·4 inches diameter holes were drilled per minute, in gypsum blocks, to a depth of 7·9 inches with water, and 4·7 inches without water. In Odenwald granite, a hole 1·7 inches diameter and fifteen and three-fourths inches deep was drilled in ten minutes.† Two thick-wire outer coils, *1* and *3*, with a thin-wire inner coil, *2*, are wound, side by side, and secured to an iron casing, completely closing in the magnetic circuit, and so forming an efficient iron-clad construction. The drill-spindle is attached to an iron core introduced into the coils. The coils

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* *Electrical World*, 1887, June 25, p. 301.

† *The Electrician.* London. Vol. xxviii, Nov. 6, 1891, p. 10.

1 and *3* are oppositely wound, so that they are equally and oppositely polarized, and connected up in series with the *rotating* brushes, R and R_2, of the generating dynamo, or of the distributing motor-dynamo; these coils are therefore traversed by an alternating current. The coil *2* is connected, at one end to the *fixed* brush F_2, and at the other end to the junction of coil *3* with the rotating brush R_1; it is therefore traversed by a pulsating current, and exerts the chief magnetizing effect upon the reciprocating iron core, with a constant polarity. Speaking kinematically of this combination of electro-magnetic elements, forming an electro-magnetic kinematic chain composed of reciprocating pairs, it is seen that the motion of the iron core is determined to a definite extent by the constant direction (polarity) and variable energizing coil *2*, in combination with the variable direction (alternating polarity) and variable energizing coils *1* and *3*. Moreover, the iron core, as an electro-magnetic link, under the influences of its electro-magnetic pairing with the energizing coils, has its motion completely constrained. This electro-magnetic constrainment of motion of the iron core link of the chain, constitutes the combination a true electro-magnetic mechanism; and when the electro-magnetic forces of nature can be compelled to do work through and by this electro-magnetic mechanism, we have a pure electro-magnetic machine. It is to be especially noted that the enveloping forms of the pairs of electro-magnetic elements, are such that there is no contact of these elements, while in mechanically-connected pairs

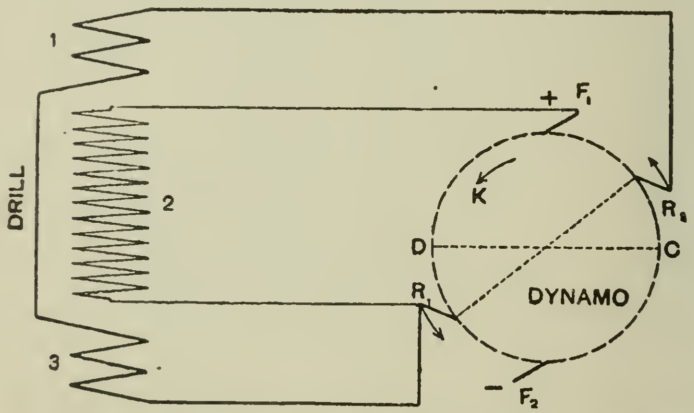

FIG. 14.—The Van Depoele reciprocating electro magnetic drill.

of elements the contact of the enveloping forms is a necessary condition to the constrainment of motion. It is therefore possible, in a pure electro-magnetic mechanism, to have constrained motion without the contact of material elements. Oftentimes practical considerations preclude the possibility of using electro-magnetically constrained motion; and, it is found best to constrain the motion mechanically by the pairing of material elements; such as, the cylindrical turning pair of elements in the dynamo or motor, and the cylindrical sliding pair of elements guiding the drill-spindle in the Van Depoele reciprocating drill.

Direct and Indirect Electro-magnetic Machines are those in which the transmission of energy, through an electro-magnetic mechanism, is of a direct or of an indirect character, according to whether the electro-magnetic forces act directly at the point of application (as in the Van Depoele mechanism), or indirectly through the intervention of other mechanism, such as a train of wheel-work, as in the Rowan machine. The indirect transmission is, in fact, through electro-magnetically *actuated* mechanisms or devices, which are of themselves essentially of another system; or which call into operation other forces of nature than the electro-magnetic forces; such as the wheel-train of the Rowan machine, transmitting the energy by purely mechanical means, from the electro-magnetic mechanism of the electric motor to the drill-spindle. It is to be remarked that the self-fixing or clamping device of the Rowan machine, acting as it does by the application of electro-magnetic traction, is an example of a locked kinematic chain, and that in this particular case such a locking, clutching or clamping action is brought about by the contact of material elements in the magnetic circuit. There are, however, examples of such a locking action with no contact of the material elements of the magnetic circuit, as may be seen in the Faraday copper-disk type of dynamo, used as a true electro-magnetic clutch or brake.

The diagram of the cycle of operations of the electro-magnetic mechanism of the Van Depoele machine, will be presented in the next paper.

CORRESPONDENCE.

To the Committee on Publications :

DEAR SIR :—I have read with great interest Mr. John Birkinbine's article upon the "Pig Iron Manufacture of the United States," in which reference is made to some of my own computations. May I venture to call Mr. Birkinbine's attention, as well as that of your readers, to the fact that in my somewhat visionary indication of the centre of the future situs of the iron industry of this country, within a circle of about 150 miles diameter, centring on the Great Smoky Mountain in North Carolina, I did not intend even to suggest that *the whole manufacture of pig iron would be concentrated within that circle.* Of course, such a suggestion as that would be absurd.

What I did intend was this : that if the development of ore within that section should be as great as the indications appeared to show that it would be, that section might become the main source of the pig iron supply. But this would not be inconsistent with the production of pig iron at many other suitable points in lesser measure, although that section might become the source of the larger part.

Were I to state the case again, in view of the more recent developments of Bessemer ores, I might perhaps take Cumberland Peak rather than the Great Smoky Mountain from which to extend a radius of seventy-five to 100 miles. But of course all such forecasts must be more or less visionary. If, for instance, the inventions for the electric concentration of ores should be as successful as their promoters hope, the low grade ores of the other sections, where they exist in excessive abundance, may be converted by concentration into Bessemer ores, thus putting a new aspect upon the case.

Again, if some of the undertakings which are apparently very promising in the line of direct processes and other methods of treating ore and fuel should prove a success, the so-called impurities in ore and coal may cease to be of consequence, and then the centre of production might fix itself at the point at which the greatest abundance of ore, coal and limestone can be assembled with the least labor and with the least length of haul. Have we yet begun to deal with heat in any but crude and wasteful methods ?

It would, of course, be an impertinence for one like myself, who has no scientific knowledge of the iron production, and who merely deals with the figures and facts as they are presented at a given date, to do anything more than to call attention to the accelerated demand for iron and steel, and to the law which pervades this branch of industry as well as every other, to-wit, that in proportion to the application of science and invention under conditions that are free from obstruction by taxation or otherwise, the abundance of this and every other material is assured at a lessening cost to the consumer, with higher rates of wages or earnings to the workman, and better conditions of life for all. In this particular instance the obstruction to the import of foreign ores has, to some extent, prevented the natural working of this beneficent law. But this is an incident, probably a very temporary one; suffice it that either at the centre indicated by myself or at some other point not very far from there, the future centre of the crude iron production of this country and of the world will probably be established.

Yours very truly, EDWARD ATKINSON.

Boston, December 31, 1891.

BOOK NOTICES.

The Practical Catechism.—A Collection of Questions on Technical Subjects, by Manufacturers and Others, and of answers thereto. By Robert Grimshaw, M.E., Ph.D. New York: John Wiley & Sons, 53 East Tenth Street. 1891.

We have here the kind of book which the poet must have had in mind when he wrote: "I mean to show things as they really are, not as they ought to be, for I avow that till we see what's what in fact, we're far from much improvement." The reviewer would have rejoiced in the possession of this book in early days when, as it seemed, he wanted to know about many things, while not a pointer could be found to tell the way to any one of them. Knowledge like hidden treasure may have existed, but there was no known way to it. If facts lie at the foundation of science, here's abundant material squared and smoothed ready for the building.

Of course, a pocket manual in diminutive, as this, can't hold everything, but any work well begun is half done, and this book gives earnest proof of the truth of this adage.

Guide books, misjudging common requirement, frequently tell what you don't want to know; but such criticism fails here, for there's not a page that does not show up well of solid grains with least chaff—grains of truth ready for the miller, and no smut machine needed. What a refreshing treat it is to get facts and data already purified of dross and well nigh adapted to immediate use! Engineering life is too short to wade through long chapters to find the meaning of a letter, or the simplest form of a usable formula, and at the end conclude perhaps, that the author has been "barking up the wrong tree," for the game the reader is after. There's no uncertain sound here, and you don't get off the scent either.

Taking a glance at the index with its forty-two pages, each having fifty or more references, the reader concludes that the author has pretty numerously covered a great variety of subjects. Beginning at absorption, which is prophetic, the reader is conducted through acids, air, alloys, dwelling in a museum of aluminium by the angle of repose, through anti-friction curves to apples and applewood, which makes the best of guides, to a checquered array of areas, thence to the atmosphere; but it is this way, in endless variety, all the way down the alphabet. The reviewer must stop, however, at belts, as one wishes to see how things look about home. This subject reminds him of an early hunt for belt data, where the published rules gave results all the way from *one* to *five*, a divergence altogether inadmissible in the realm of machine economy.

Our author of wide and later research finds a happy medium between utter *insufficiency* and enormous *excess*, giving for use the figures fifty to sixty-six pounds per inch of width, at any velocity, as a fair carrying capacity of single belts, while we may add that, if forty to sixty-six pounds be taken, these figures will embrace those concluded upon by many good modern authorities, who stand squarely upon successful practice.

It seems idle to dwell upon so small a matter, but it takes a great deal of time and a wide experience often to arrive at a simple general statement or rule, which will compass the needs of usual practice; in this book we have much of this kind of data in a very get-at-able shape.

The many sources from which this matter has been obtained, must give it value, and the occasions and opportunities for securing it being rare and fruitful, must add to and greatly reinforce that value. Out of the great mass of material, a judicious selection has been made, such as would benefit the largest number of practical men; to this class of readers the author commends his work, and the reviewer seconds his invitation to the feast of facts, which he has prepared and set forth in this little volume. J. H C.

The Metallurgy of Silver, Gold and Mercury in the United States. By Thomas Egleston, LL.D., etc. Vol. II. Gold and Mercury. New York: John Wiley & Sons. 1890.

The review of the second volume has been so long delayed (through no fault of the Franklin Institute) that much which would otherwise have been said is rendered unnecessary, inasmuch as other reviews have said it. This volume is a great improvement over the first, both on account of what it contains and of what it omits. Its eight chapters, covering 901 pages, contain much interesting and important matter. The historical part of the subject, while not always free from error, is well treated, and shows evidence of careful research.

The illustrations and descriptions of the various kinds of mining, with the statistics of cost, will make this book always necessary as a book of reference. The pages devoted to the measurement, management and cost of water are full of important matter, as are those on "débris litigation." The processes of drill mining and the description of the preparation works follow those of flumes, ditches and sluices.

After the mills comes the metallurgical operation of roasting. The leaching and quartation, the melting and minting, occupy seven of the eight chapters, and 798 of the 900 pages. The last chapter is devoted to mercury, its ores, its treatment and production, and its cost.

Altogether it may be said to be the most complete compendium of the prospecting, mining, producing and assaying of gold and mercury which can be found in the language. A very full index makes the work still more valuable. It will be a necessity in the library of all who are interested in the subjects treated, and who can afford to buy it. F.

The Phosphates of America. When and How they Occur; How they are Mined and what they Cost, with Practical Treatises on the Manufacture of Sulphuric Acid, etc. By Francis Wyatt. Second edition. New York: The Scientific Publishing Company.

This is a valuable book of 178 pages, royal 8vo, which gives besides a general introduction on the agricultural side of phosphates, a history of the apatite mines of Canada, belonging to the Archean division of the geological scale, and the bone or rock phosphates of the Cenozoic age in South Carolina and Florida. The manner of occurrence, relation to the surrounding rocks, methods of exploitation and of mining, the laws relating to the subject and the statistics of production are all given with the succinctness and method of one who is a master of this subject and who is familiar with the presentation of philosophical papers. It is illustrated richly by photo-engravings which add very much to the clearness of the work.

Chapter VIII is consecrated to the best methods of phosphate, limestone, pyrites, etc., analysis, and this is thoroughly taken up.

The last eleven pages of the work are concerned with directions for the preparation of the necessary laboratory reagents, useful tables for computation, etc.

It covers a field entirely its own and covers it so well that it must be accessible to any one who is interested in phosphates; indeed, even if the book were only half as reliable as it is, the chemist, geologist, manufacturer and shipping merchant would need it for reference. F.

The Washington Bridge over the Harlem River at One-hundred-and-eighty-first Street, New York. A description of its construction. By William R. Hutton, Chief Engineer. New York: Leo von Rosenberg. Price, $8.

The monograph above cited is similar in style to other publications, descriptive of special engineering works, issued by the same publisher. It forms in itself an exhaustive description of the important structure of which it treats, and will prove a most valuable work for the bridge designer and constructor, for whom it is specially intended.

As will be inferred from the foregoing remarks, the feature of the work which gives it its peculiar value to the specialist resides in the illustrations, which comprise general views and plans, views of the work in different stages of completion, views of the completed structure, of the iron work, of the details of the masonry and superstructure, etc. These illustrations give a complete description of the bridge from the engineering standpoint.

The text covers a descriptive account of the construction, and copies of the contract and specifications, which, with the wealth of illustrations, constitute one of the most complete and satisfactory monographs that it has been our pleasure to notice in these columns.

We cannot refrain from special commendation of the illustrations, which are executed in admirable style, and of the mechanical excellence of the work as a whole, which reflects credit on the publisher. The engineering profession in America will, no doubt, duly appreciate these facts. W.

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For 1891.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1891 :

MEMBERS.

Members at the close of 1890, ...	2,169	
Number of new members elected who have paid their dues, ...	112	
		2,281
Lost by death or resignation, ...	99	
Dropped for non-payment of dues, ...	109	
		208
Total membership at close of 1890, ...		2,073

FINANCIAL STATEMENT.

Balance on hand January 1, 1891, ...		$657 71
Receipts :		
Contributions from members, annual, . . .	$5,771 00	
Contributions from members, life, ...	580 00	
Certificates of stock, second class, ...	60 00	
Income from legacy of Geo. S. Pepper, . .	1,034 30	
Income from estate of John Turner , . . .	13 25	
Income from Bloomfield Moore fund, . . .	750 00	
Income from memorial library fund, . . .	57 17	
Interest on investments new building fund,	340 00	
Interest on B. H. Bartol fund, ...	60 00	
New building fund subscriptions, ...	150 00	
Interest on investment of Institute funds, .	794 00	
Temporary loan, ...	3,200 00	
Cash from subscriptions to, and sales of, the *Journal*, fees for drawing school and other sources, ...	10,248 66	
		23,058 38
		$23,716 09

Payments:

Committee on library,	$1,703 03	
Committee on instruction,	2,573 12	
Curators,	2,238 20	
Salaries and wages,	4,420 91	
Insurances,	900 00	
Bloomfield Moore fund expenditures.	683 78	
Memorial library fund expenditures,	31 69	
Investment memorial library fund,	105 20	
Board of Trustees, subscription to new building fund,	150 00	
Temporary loan,	2,200 00	
Interest on temporary loan,	85 84	
Other expenditures,	8,274 65	
		$23,366 42
Balance on hand, December 31, 1891,		$349 67

LIBRARY.

The additions made to the Institute's collection of books and miscellaneous publications during the past year have been somewhat greater than the average of late years, exhibiting an increase of about thirty per cent. over the figures of the previous year.

The details of the operations of the library appear in the committee's annual report to which the board refers.

No change has been found necessary or desirable in the rules regulating the use of the library by the public, which shows a steady increase, and but one case of the abuse of the non-members' privilege has been reported by the committee.

The Committee on the Library has strongly urged upon the board the necessity of taking measures looking to the more adequate protection of the building against destruction by fire, and at the present time, several suggested plans for accomplishing this object are under consideration. In connection with this important subject, the board desires to call attention to the fact that the very limited financial resources of the Institute interpose a serious obstacle to carrying any suitable plan into effect.

THE JOURNAL.

The annual report of the Chairman of the Committee on Publications, exhibits the fact that the *Journal* has continued to be self-supporting during the past year. The board desires, however, to emphasize the fact that this condition of things is due in much larger measure to good management than to the generous patronage of the members of the Institute.

In evidence of this it will suffice to state the fact that of the total income of the *Journal*, from subscriptions, advertisements, sales of copies, etc., less than ten per cent. is derived from the membership of the Institute.

While expressing its satisfaction with the present direction of the affairs of the *Journal*, the board renews its recommendation to members to support it more liberally.

It is the only record in which the educational and scientific work of the Institute is preserved, and the only means by which its activity is made known to the world, and has contributed more powerfully than all the other agencies at our command to establish and sustain the high reputation which the Institute enjoys. The Committee on Publications at present is carefully considering certain plans for extending the influence and usefulness of the *Journal*, which, when matured, it is hoped, will meet the cordial approbation of the members.

COMMITTEE ON SCIENCE AND THE ARTS.

The record of the work of the Committee on Science and the Arts during the past year is highly creditable.

The number of cases upon which reports were made is about the same as in the previous year, and of these, several were of unusual importance, and entailed great labor in their investigation. The committee is about to enter upon the sixth year of its existence as an elected body, and the greatly increased efficiency of its work affords conclusive evidence of the wisdom of the change effected in its organization.

The board refers to the annual report of the Chairman of the Committee for the details of its work.

LECTURES.

The Committee on Instruction has found no cause to depart from its policy pursued for the past five or six years, of inviting men of note to lecture before the Institute, and thanks to the zealous co-operation of the professors, the committee has been enabled to offer the members a series of lectures of excellent character.

The lectures delivered under the committee's auspices during the year 1891, numbered thirty-one, of which seventeen were of such scientific importance or technical interest as to warrant their publication in the *Journal.*

THE DRAWING SCHOOL.

The number of pupils in the Drawing School, in 1891, exceeded that of any previous year, and the board is gratified to be able to assure the Institute of the continual efficiency.

The figures of attendance are as follows:

At the spring term of 1891,	247
At the winter term of 1891,	258
Total,	505

An increase of thirty-two over that of the previous year.

SECTIONS.

The past year exhibited a gratifying growth of interest in this branch of the Institute work.

An inspection of the annual reports of the Chemical and Electrical Sections, appended hereto, will show considerable additions to the membership and an increase in the amount of work accomplished. The papersr ead at the section meetings afford very desirable material for the *Journal*, and add greatly to its interest, but the greatest benefit of the sections is to be found in the stimulus they give to the work of original research, which cannot be overestimated.

STATE WEATHER SERVICE.

The failure of the State to continue the appropriation for the expenses of the State Weather Service compelled the Committee on Meteorology to abandon the publication of the monthly reports. The committee has been enabled, however, with the assistance of the United States Weather Service, to maintain the organization of its work in the several counties of the State, and to continue, as heretofore, the collection of meteorological data, which are duly preserved, and which it hopes in time to be able to put in print. It is the committee's hope that at the next session of the Legislature, the appropriation for the continuance of this important work will be granted.

GENERAL REMARKS.

It is greatly to be regretted that the amount of receipts for membership is less than that of the previous year, and that the flattering exhibit of the year 1889 has not been maintained. The active work which was accomplished during 1889 by the Committee on Membership, seems to have languished, and to this must be attributed almost entirely the falling off in the accession to membership.

As a consequence, the financial exhibit for the coming year is not an encouraging one. With a city of over 1,000,000 inhabitants, and preeminently a manufacturing city, there is no practical reason why an institution organized as the Franklin Institute is for the promotion of the mechanic arts, established for nearly seventy years, and doing the effective work that is here done, should not have at least 5,000 members.

There is no sounder method of promoting the efficiency of such a school than this, and every cent added to its income adds so much more to the actual wealth of the city through its manufacturing interests.

Will not those who are members and those who are not, give this subject their serious consideration, and act for the good of the Institute and for the manufacturing interests of the city, the former by obtaining new members, and the latter by becoming members themselves ?

Attention has already been called to the very limited resources of the Institute, interposing a serious obstacle to the adoption of any plan for the proper protection of the building, and its valuable library from fire.

This poverty of resources is felt in all the operations of the Institute, seriously restricting the extent of its work and depriving the membership and the community of advantages that would be of incalculable value to mechanics and artisans. With a new building and fire-proof library, with laboratories properly equipped, the Institute could use its great latent force as a centre of unrivalled influence in the field of mechanic arts. It only needs an impetus on the part of some of our large-hearted citizens to accomplish this purpose so long cherished and heretofore fruitlessly attempted.

By order of the Board,

[SIGNED] JOS. M. WILSON,
President.

HALL OF THE INSTITUTE,
PHILADELPHIA, January 13, 1892.

ANNUAL REPORT OF THE COMMITTEE ON THE LIBRARY.

(For 1891.)

PHILADELPHIA, January 12, 1892.

To the President and Members of the Institute:

The Committee on Library respectfully reports the following summary statement of the operations of the library during the past year.

During the year the following additions were made:

Bound volumes,	1,508	
Unbound volumes,	660	
Pamphlets,	2,211	
Miscellaneous publications,	183	
Total additions,		4,562
Being an increase over the previous year of		1,263
The total number of volumes in the library at the close of 1890 was	35,015	
The additions of 1891 numbered	2,168	
Making the number of volumes at the end of the year 1891,		37,183
The total number of pamphlets in the library at the close of 1890 was	20,982	
The additions in 1891 numbered	2,211	
Making the number of pamphlets at the close of 1891,		22,183
The miscellaneous publications, such as maps and charts, designs and drawings, photographs, lithographs, manuscripts, etc., at the close of 1891 number		3,912

In addition to the above, the library possesses, in duplicates, as follows:

Bound and unbound volumes,	1,515
Pamphlets,	3,667
Periodicals (numbers),	2,119

The number of periodicals and publications of societies received by the library in exchange for the *Journal* of the Institute, at the close of the year 1891 was 380.

Among the noteworthy additions made during the past year, there should be named the patent reports of Switzerland, a complete set of which was presented to the Institute by the Swiss Government, also a number of important chemical journals, contributed by the Chemical Section ; while the increased income received from the Bloomfield H. Moore Fund has enabled the committee to increase considerably the number and value of its purchases from this endowment.

The committee finds that the regulations relating to the use of the library for reference by non-members, which were put in force in 1887, though imposing considerable extra labor upon the librarian and his assistants, afford a satisfactory solution of what, previous to that time, had been a troublesome problem. During the past year, only a single case was reported in which the privileges were abused. The value placed by the public upon the privileges granted, is shown by the fact that during the year, nearly 1,000 non-members visited the library, consulting over 4,250 books and periodicals, of which more than three-fourths were patent reports, and the remainder, volumes and pamphlets on miscellaneous subjects.

The committee regrets that the chronic difficulty of lack of space is felt with increasing severity, as time passes.

At the committee's urgent solicitation, the board has made provision for the better protection of the library from destruction by fire, by authorizing the covering of a number of exposed windows with fire-proof shutters, which will soon be put in place. Respectfully submitted,

[SIGNED] W. P. TATHAM,

Chairman of Committee on the Library.

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

(For 1891.)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 4, 1892.

To the President and Members of the Franklin Institute :

The chairman of the Committee on Science and the Arts respectfully submits the following report of the operation of the committee for the year ending December, 1891 :

At the opening of this year, there were forty applications for examination under consideration and awaiting action.

The number of new applications received during the year is .	53
Of these there were accepted for examination and report, . .	46
There were declined, ...	5
And withdrawn, ...	3
The number of reports considered was	54

Adopted finally,	41
Advisory reports adopted,	3
Applications dismissed for insufficient information,	9
Applications under consideration by sub-committee at end of year,	40
Reports pending action of committee,	8

The recommendations of award of medals during the year were:

Of Elliott Cresson Medals,	3
Of the John Scott Legacy medals and premiums,	17

Medals granted and delivered during the year:

Elliott Cresson Medals,	3
John Scott Legacy Medals and Premiums,	15
Edward Longstreth Medals,	5
Certificates of Merit,	2

Medals awarded and held pending advertisement:

Elliott Cresson,	2
John Scott Legacy,	4

One protest against an award made by the committee has been received, which upon investigation did not appear to be sustained by evidence and was dismissed.

Several of the examinations made by the sub-committee during the past year embraced subjects of unusual interest and importance in the arts and involved in several cases a great deal of painstaking and exhaustive research, and more than usual expenditures in conducting them.

During this year a regulation has been operative requiring with each accepted application for examination the deposit of $5 with the actuary to defray the cost of necessary printing and illustration and searches into the state of art as shown in patent records, which regulation has been cheerfully acquiesced in by the applicants, and has been found to facilitate the work of the sub-committee by avoiding the delays incident to procuring such assistance through a correspondence between sub-committees and applicants through the secretary.

The classification and indexing of reports has been continued to date, and the addition to the indices to reports will appear in the *Journal* in due course.

During the year the committee has completed the arrangements for tests of hot-water heaters, in prescribing appliances to be used and regulations to govern such tests, in compliance with the request of the publishers of the *Metal Worker*, and the making of such tests by the advanced students of the engineering classes of the University, under the supervision of a sub-committee, has been arranged by Prof. H. W. Spangler in a most satisfactory manner.

The receipts during the year from all sources were	$609 21
Expenditures,	600 14
Showing a balance in the committee's favor, of	$9 07

The work of the committee has been a source of income from the profit of sales of extra editions of the *Journal* containing reports of the committee, which profits reappear in the receipts of the Committee on Publications.

The record of this year is, upon the whole, a satisfactory showing that the committee has fully worked up to the facilities afforded, and the character of inventions submitted for examination and the increasing demand for publications containing their reports clearly indicate public appreciation and approval.

S. LLOYD WIEGAND,
[SIGNED] *Chairman.*

REPORT OF THE CHEMICAL SECTION.

(For 1891.)

Mr. Joseph M. Wilson, President Franklin Institute.

SIR:—I have the honor to submit the following report of the proceedings of the Chemical Section, for the year 1891.

A consideration of the present condition of the section, and also of its history during the past year, shows that it has made very satisfactory progress for that interval. The work was prosecuted with the aid of the following officers:

President,	DR. WM. H. WAHL.
Vice-Presidents,	MR. H. PEMBERTON, Jr. DR. WM. H. GREENE
Secretary,	DR. WM. C. DAY.
Treasurer,	DR. H. W. JAYNE.
Conservator,	DR. WM. H. WAHL.

Stated meetings were held as required by the by-laws, on the third Tuesday of each month, excepting July and August.

Membership: The number of members on the treasurer's books at the beginning of the year was seventy-two; since that time twenty new members have been elected, eight have resigned, and two were dropped for non-payment of dues; this making a net gain of ten, or a total membership of eighty-two.

Finances: The report of the treasurer recently submitted to the Section shows that the total receipts from various sources during the year exceeded the expenditures, leaving a cash balance in the treasurer's hands at the close of the year.

The attendance upon the meetings has been satisfactory throughout the year, and fully equal to that of 1890.

The highest purpose that the section can serve is, of course, in its capacity as a medium for encouraging and stimulating original research among chemists. That this purpose has been promoted during the past year is well demonstrated by the fact that twenty-nine papers, giving the results of original investigation, were read before the section and published in the *Journal* of the Institute. In addition to these, four other communications were presented, thus making a total of thirty-three subjects of scientific interest which were considered at ten regular meetings.

Very respectfully submitted,
Wm. C. Day, *Secretary.*

REPORT OF THE ELECTRICAL SECTION.

(For 1891.)

The President and Members of the Franklin Institute:

The Secretary of the Electrical Section begs leave to present the following report of the proceedings of the section, for 1891:

An application for the formation of an Electrical Section, made in accordance with section 3, of article xi, of the by-laws, was presented to the Board of Managers and approved by them, and reported to the Institute with the names of the founders, at its stated meeting, December 17, 1890. After two preliminary meetings, the section was organized on February 24, 1891, by the adoption of its by-laws and the election of the following officers:

President,	Prof. Edwin J. Houston.
Vice-Presidents,	Mr. Carl Hering. Mr. Pedro G. Salom.
Secretary,	Prof. L. F. Rondinella.
Treasurer,	Dr. Wm. H. Wahl.
Conservator,	

The membership has increased from sixteen founders to sixty-eight active and associate members now on the roll, and the section has lost two members by resignation and one by death.

Seven stated meetings have been held, in accordance with the section's by-laws, on the first Tuesday of each month excepting July and August, with an average attendance of thirty members and visitors at each meeting.

The communications that have been presented during the year, may be found printed in full in the *Journal* of the Institute, and in the present volume of the Proceedings of the section.

In addition to these, many open questions have been discussed, and several electrical devices have been exhibited and described, so that every meeting has been interesting and profitable.

The growth of the section in every way during the short period of its existence has been very gratifying, and it is hoped and believed that it will continue in the future, so that its work may assist in maintaining the scientific *prestige* of the Institute in the department of electricity.

Respectfully submitted,
L. F. Rondinella, *Secretary.*

Philadelphia, January 5, 1892.

Franklin Institute.

[*Proceedings of the annual meeting, held Wednesday, January 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 20, 1892.

Mr. JOS. M. WILSON, President, in the chair.

Present, 174 members and thirty-four visitors.

Additions to membership since last report, seven.

The annual reports of the Board of Managers, and of the Standing Committees were presented and accepted. (The reports appear elsewhere in this impression of the *Journal.*)

Mr. Henry G. Bryant gave an account of his expedition successfully undertaken in the autumn of last year, to the Falls of the Grand River, in Labrador. The speaker illustrated the subject by the exhibition of a series of lantern slides, from photographs taken by himself. The speaker was heartily applauded for his extremely interesting presentation of the subject.

Prof. Lewis M. Haupt, by invitation, described the project of a ship canal across New Jersey, to unite New York and Philadelphia, and set forth the advantages—commercial and military—to be anticipated from the construction of such a navigable water-way. At the close of Prof. Haupt's remarks, Mr. Heyl offered the following preamble and resolution, which were adopted, viz:

Recognizing the national importance of the proposed ship canal connecting the waters of the Delaware River and Raritan Bay, in the interest of manufacturing and mercantile industries,

The Franklin Institute of the State of Pennsylvania hereby *resolves*, that a committee of three of its members be appointed to coöperate with similar committees of the New York Board of Trade and Transportation, and of the Trades League and other organizations of Philadelphia, in their endeavors to carry the following resolution, recently adopted by them, into effect:

Resolved, That the Members of Congress from this State be requested to urge the introduction of an item in the river and harbor bill, making an appropriation of a sum not less than $25,000 for an examination, survey, and report upon a twenty-four foot navigable channel between Raritan Bay and the Delaware River; said appropriation to be expended by a commission to be composed of one citizen from each of the States of New York, Pennsylvania and New Jersey, to be appointed by the Governors thereof, and one officer of the United States Corps of Engineers, one officer from the Navy, and one officer from the United States Coast Survey.

Mr. John Carbutt exhibited a suite of beautifully colored lantern views, by Japanese artists, relating to the recent destructive earthquake that had devastated a portion of Japan. (The pictures were obtained from the collection of Dr. Edward Williams.) Mr. W. N. Jennings showed an interesting series of pictures illustrative of street scenes in Boston.

The Secretary's report was devoted to a description of a collection of interesting specimens illustrating the most recent advances in the application of aluminium in the arts, which were shown by the courtesy of the Pittsburgh Reduction Company. These specimens will be specially described in the lecture of Mr. A. E. Hunt on "Aluminium, from an Engineering Standpoint," which will appear in the *Journal* at an early date.

The tellers of the annual election made their report of the result of the election held this day, between the hours of 4–8 P. M., and were discharged with a vote of thanks. The President thereupon declared the result of the election to be as follows:

For *President*	(to serve one year), . .	JOS. M. WILSON.
" *Vice-president*	(" three years), . .	EDWARD LONGSTRETH,
" *Secretary*	(" one year), . .	WM. H. WAHL.
" *Treasurer*	(" " "), . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . .	WM. A. CHEYNEY,

For *Managers* (to serve three years),

JOHN E. CODMAN,
GEORGE V. CRESSON,
EDWIN J. HOUSTON,
ENOCH LEWIS,
JOHN LUCAS,
SAM'L P. SADTLER,
WM. H. THORNE,
JOHN C. TRAUTWINE, JR.

For members of the *Committee on Science and the Arts* (to serve three years),

L. L. CHENEY,
ARTHUR CHURCH,
C. M. CRESSON,
JAMES CHRISTIE,
D. E. CROSBY,
J. M. EMANUEL,
J. L. GILL, JR.,
J. F. HASKINS,
CARL HERING,
S. R. MARSHALL,
WM. McDEVITT,
C. E. RONALDSON,
SAMUEL SARTAIN,
T. C. SMITH,
S. L. WIEGAND.

Adjourned.

WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXXXIII. MARCH, 1892. No. 3

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

BEARING METAL ALLOYS.*

By C. B. Dudley, Ph.D.,
Chemist to the Pennsylvania R. R. Co.

[*Concluded from p. 93.*]

It will be observed that the method was to compare the relative loss of metal by wear of various alloys with a certain standard alloy. It should be stated that likewise observations were made on the behavior of the experimental alloys as to heating. No observations were made as to the difference in friction with the different alloys. This field is entirely unexplored, so far as I know. The first test was a comparison of the old copper-tin alloy with the standard phosphor-bronze bearing metal. The results obtained were as follows:

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* Abstract of a lecture delivered before the Franklin Institute.

COPPER-TIN VS. PHOSPHOR-BRONZE.

	Composition Copper-tin Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper,	87·50	79·70
Tin,	12·50	10·00
Lead,	none	9·50
Phosphorus,	none	0·80

Wear.—First experiment, copper-tin wore forty-eight per cent. faster than phosphor-bronze; second experiment, copper-tin wore fifty-three per cent. faster than phosphor-bronze; third experiment, copper-tin wore forty-seven per cent. faster than phosphor-bronze.

It should be stated that the analyses are approximately average analyses, rather than special analyses of the samples in each test, and it will be observed that there is no allowance for small impurities of zinc, iron, antimony, etc. It will be observed also that in expressing the loss of metal by wear, the loss is given in percentages of loss of metal compared with standard phosphor-bronze. It is entirely clear, we think, from the above experiments that the copper-tin alloy of seven to one, is nothing like as valuable as the standard phosphor-bronze for bearing metal, and this view is confirmed from knowing that the experiments above given were made on some hundred bearings of each kind, and that a much larger percentage of the copper-tin bearings heated than the phosphor-bronze. So satisfactory were these experiments that the phosphor-bronze bearing metal was for quite a long time used as the standard bearing metal for car bearings on the Pennsylvania Railroad. It was not deemed advisable to allow the matter to rest there, and accordingly experiments have constantly been in progress to secure modifications which would give better results. Just here I would like to call attention to a matter of importance. You will observe that the copper-tin bearing metal differs from the phosphor-bronze in several particulars. First, the phosphor-bronze has less tin; second, it has quite a percentage of lead, and third, it has some phosphorus. Please make a note of these points as they will be referred to later.

It is not intended to give the results of all the tests that have been made during the last fifteen years, but only such a selection from them, as will apparently illustrate a law, and show the development of our knowledge leading to present practice. Accordingly, the next experiment will be one which we think throws considerable light on the matter, namely, an experiment with arsenic-bronze. It has been found that arsenic practically takes the place of phosphorus in a copper-tin alloy. Accordingly, several experiments were made with arsenic-bronze. The results of these experiments are as follows:

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*First experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper, ...	89·20	79·70
Tin, ...	10·00	10·00
Lead, ...	none	9·50
Phosphorus, ...	none	0·80
Arsenic, ...	0·80	none

Wear.—Arsenic-bronze wore forty-two per cent. faster than phosphor-bronze.

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*Second experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper, ...	79·20	79·70
Tin, ...	10·00	10·00
Lead, ...	7·00	9·50
Phosphorus, ...	none	0 80
Arsenic, ...	0·80	none

Wear.—Arsenic bronze wore fifteen per cent. faster than phosphor-bronze.

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*Third experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper, ...	79·70	79·70
Tin, ...	10·00	10·00
Lead, ...	9·50	9·50
Phosphorus, ...	none	0·80
Arsenic, ...	0·80	none

Wear.—Arsenic bronze wore one per cent. faster than phosphor-bronze.

It will be observed that the first experiment was practically a copper-tin alloy containing some arsenic, and that this wore very nearly as fast as the copper-tin alloy seven to one. I have been accustomed to regard this experiment as indicating that the phosphorus in bearing metal alloys does not have very valuable influences on the wear, and as has already been hinted at in the earlier part of the lecture, the phosphorus seems to be more valuable in the foundry than in the service. The second experiment, it will be noted, differs from the first in introducing some lead in the alloy, and it is extremely interesting to note that although the arsenic and tin remain the same as in the first experiment, the introduction of the lead produces a diminution in the rate of wear which is very marked. After this experiment was concluded, a third experiment was tried in which the composition of the arsenic-bronze was patterned as near as possible after that of the phosphor-bronze, and it is interesting to note that in this case the wear of the two was almost the same. The heating of the arsenic-bronze alloys in service was no greater than the phosphor-bronze, and there were no other appreciable differences to be discovered in the behavior of the metal, except as the figures above show the rate of wear.

It is interesting to note that these experiments thus far made seem to indicate first, that the introduction of phosphorus or arsenic into a bearing metal has very little influence on the rate of wear, while the introduction of lead has a very marked influence on the rate of wear.

In view of these teachings, it was decided to extend still further the influence of lead on bearing metal. Accordingly, a bearing metal was obtained which contained still more lead than the standard phosphor-bronze. This metal we will call "K" bronze. The result of the experiment with "K" bronze is as follows:

"K" BRONZE VS. PHOSPHOR-BRONZE.

	Composition "K" bronze. Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper, ...	77·00	79·70
Tin, ...	10·50	10·00
Lead, ...	12·50	9·50
Phosphorus, ...	none	0·80

Wear.—First experiment, "K" bronze wore eight per cent. slower than phosphor-bronze; second experiment, "K" bronze wore 7·30 per cent. slower than phosphor-bronze.

This experiment to my mind is extremely interesting. It should be said that no trouble was experienced from heating with the "K" bronze, more than with phosphor-bronze, and no other peculiarities, other than the rate of wear as given, were observable. There is no phosphorus in the "K" bronze; practically the same tin, and an increase in lead, and as the result of these changes, the "K" bronze, as will be observed, surpasses the phosphor-bronze in wear. It seems almost indisputable, that we are certainly on the right track in the matter of developing a bearing metal which will be satisfactory in every sense in service.

The value of lead in a copper-tin alloy for bearing metal, being apparently so well established, it became a question of how much lead could be gotten into the alloy without running into difficulty. Also about this time there began to be evidences of a law, governing the composition of all bearing metal alloys, which law may be briefly stated as follows:

"That alloy which has the greatest power of distortion without rupture, will give best results in wear." We will refer to this law, and show a possible broadening of it, into a more general law a little later, but at this time in accordance with this law, we started to design an alloy which would have as great power of distortion as possible without rupture. To do this we attacked the problem from two stand-points; first, the proportions of copper and tin, and then this having been established, the proportion of lead. Upon the first of these two points there are some very interesting data. It is common knowledge that an alloy of two parts copper to one of tin, which is usually called "speculum metal," is one of the most brittle substances known. I have a sample here, and you will observe that by simply dropping this piece, which is 2 inches wide, 3 inches long, by ¼ inch thick, upon the floor from the height of the table, it breaks into a large number of pieces. Also if I lay it on an anvil and take a hammer and strike it, it flies even worse than glass, and is readily pulverized. This speculum metal will suffer almost no distortion, therefore, without rupture. It can neither be bent nor distorted in any way without breaking. If now the percentage is changed, and an alloy is made of three parts copper to one of tin, we get a substance which is less brittle. Four parts copper to one of tin, is still less brittle, and begins to be a metal which will suffer some distortion without rupture. Five parts copper to one of tin is common bell metal. Seven parts copper to one of tin is, as has already been described, the well-known cannon bronze, which has also been largely used as a bearing metal. The point that I want to make, and that seems clear to me, is that a metal can be made out of copper and tin, which will suffer more and more distortion without rupture, by diminishing the tin and increasing the copper. After experimenting somewhat in this line, we finally decided on a proportion of copper and tin, about nine and one-half parts copper to one of tin. We have some evidence, obtained since the experiments I am about to give you were made, that indicate that we could have gone still farther, and made the ratio of copper to tin, twelve or possibly fifteen copper to one of tin. This point has not yet been definitely proven. The ratio of copper to tin having been established, the question of how much lead to use came up, and as a consequence the question of the influence of lead on a copper-tin alloy arose. I do not think that this point has been fully worked out, but as far as we have gone, the indication seems to be, that the addition of lead has much the same influence on a copper-tin alloy, that a still further diminution of tin would have. That is to say, if an alloy of copper and tin is made, fifteen parts copper to one of tin, it will probably have much the same physical properties, and give much the same results in wear, as an alloy of ten parts copper to one of tin, which alloy contains quite a large percentage of lead. I say this point has not yet been fully worked out, but what indications we have point in this direction. It should be stated here, that as the amount of tin is diminished, and the amount of lead is increased, the tendency of the metal to yield more readily under pressure increases, so that it becomes essential to guard against possible dangers of having a metal which would yield too readily under the load. After considerable preliminary work, bearings were cast, and a wearing test made, the results of which are as follows, the new metal being called alloy "B:"

ALLOY "B" VS. PHOSPHOR-BRONZE.

	Composition Alloy "B." Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper, ...	77·00	79·70
Tin, ...	8·00	10·00
Lead, ...	15·00	9·50
Phosphorus, ...	none	0·80

PHYSICAL PROPERTIES.

	Alloy "B."	*Phosphor-bronze.*
Tensile strength, per square inch, pounds, . .	24,000	30,000
Elongation, per cent., ...	11	6

Wear.—Experimental alloy "B" wore 13·50 per cent. slower than phosphor-bronze.

It will be observed that this alloy wears considerably better than the standard phosphor-bronze, and the best of any in the series; also, that it is lower in tin and higher in lead than the phosphor-bronze. It will also be observed that the physical properties of alloy "B" were taken in comparison with phosphor-bronze, and that the characteristics are that alloy "B" has a lower tensile strength, but a greater elongation than the phosphor-bronze. It is well known that the elongation measures to a greater or less extent, the capacity of the metal to suffer distortion without rupture. Those metals which can be tied in a knot, so to speak, have the greatest elongation, when subjected to the ordinary physical test of pulling until rupture takes place. The alloy "B" above given, with a slight modification which enables the Pennsylvania Railroad to use the large amount of phosphor-bronze scrap that it has, is the standard bearing metal of that road, and is regarded as the best that is now known on the subject of bearing metal alloys. It is not at all certain, however, that a still further modification in the diminution of tin and increase of lead, would not give even better results. Some experiments have been made toward still further diminishing the tin, and increasing the lead, but it is found that a certain amount of tin is necessary to hold the lead alloyed with the copper, and apparently the limit of the diminution of tin and increase of lead is not a great ways from the composition of alloy "B." Of course, it will be agreed that when the lead will not stay alloyed long enough to allow successful castings to be made, the limit of diminution of tin and increase of lead has been reached, and there are some indications as stated above that the analysis above given is not a great ways from the limit.

The formula used on the Pennsylvania Railroad in making the standard bearings patterned after alloy "B" is as follows:

	Pounds.
Copper,	105
Phosphor-bronze, new or scrap,	60
Tin,	9¾
Lead,	25¼

By using ordinary care in the foundry, keeping the metal fairly well covered with charcoal during the melting, it is entirely possible to get perfectly successful castings in car bearings on the above formula. The copper and the phosphor-bronze can be put in the pot all at once before putting in the melting hole. The tin and lead should be added after the pot is taken from the fire. This formula gives approximately the analysis under the heading Ex. B Metal, mentioned in the earlier part of this lecture.

It is of course a fair question whether the introduction of a little zinc, or possibly some other combinations of the six or eight metals commonly used for alloys, will not give a bearing metal much better than the alloy "B." All that I can say on this point is that alloy "B" represents the best knowledge that we have on the subject at present, and the whole thing may be summed up by saying that at present the best bearing metal that we know of, is a copper-tin-lead alloy, containing a small amount of phosphorus, in which the proportions of the constituents are approximately those shown above.

It has already been stated that a satisfactory bearing metal should be of such a nature that it will sustain the load without crushing; that it will work well in the foundry; that it will not heat readily; that it will make the friction between the rubbing surfaces as low as possible, and that it will give the highest possible mileage, with the smallest possible loss of metal by wear. It is believed that the metal which has been last described fulfils all these requisites as well as any alloy now known. Of course, the most important element; that is to say, the one which bears the closest relation to dollars and cents in a great corporation, is obviously the wear, and any light which can be thrown on this subject will, of course, have a tendency to diminish the operating expenses, or what amounts to the same thing, leave more money in the treasury of a corporation at the end of the year, so far as operating expenses are affected by bearing metal. In the course of our study on this subject, we have philosophized a little on the question of wear, and have endeavored as much as possible to find out what property it was in metals, which enabled them to resist loss of metal by abrasion. We have already hinted at the possibility of a law governing this phenomenon of loss of metal by wear, but the law, as enunciated, seems to be too narrow. Much light has been thrown on the subject from the study of other metals, and in other fields besides that of bearings; and in view of the importance of the subject, the following considerations, in regard to wear, may not inappropriately close this lecture:

Of course, wear is influenced by the conditions under which it takes place, and it is not my purpose to discuss those variables, which may fairly enough be called "concomitant conditions." I will, therefore, not discuss lubrication, pressure, speed, temperature, rolling friction, or abrasion, nor, indeed, the nature of the two metals rolling or sliding over each other, but will confine myself wholly to the qualities of metal which, all other things being equal, give least loss of substance by wear under the same service. To my mind, we are justified in assuming that at least three elements enter into the problem of wear.

(1) That metal which will suffer the most distortion without rupture will wear best. This quality of metal is usually

measured or expressed in figures by the well-known physical data "elongation" or stretch before rupture in the common physical test. Possibly the experimental data on this point is greater than we possess on any other of the variables which enter into wear. If we may trust the data which I have brought forward, and the conclusions drawn from them, in all cases the greatest elongation is characterized by the best wear; or, according to the law, that metal which is characterized by the greatest power to resist distortion without rupture will wear best.

(2) The first variable being obtained in satisfactory amount, an increase in tensile strength will add to the wearing power of the metal. The diminution of tensile strength, which is characterized by the better-wearing metals, according to our data, is not, if I am correct, a desirable quality. It is a concomitant of most metal, that as it increases in its power of elongation, or stretch, before rupture, it diminishes in tensile strength. If, on the other hand, a new metal could be found which, with any given elongation, was characterized by a higher tensile strength than some old and well-known metal with the same elongation, the new metal would, if the theory is correct, wear better than the old one. It is not difficult to say why an increase in tensile strength should be valuable in assisting wear, provided the power of distortion before rupture is not interfered with. Wear, as I understand it, is the tearing off of minute particles, and if in one case it requires more force to tear off the particles than in another, the wear in that case will be slower. We have, I think, some experimental data which point in this direction. The wear of bearings per thousand miles is about three times as fast as the wear of axles; in other words, as has already been stated, the standard phosphor-bronze bearing metal loses about a pound for each 25,000 miles that the bearing moves. The axle under it loses about a pound for each 75,000 miles, but the metal of the axle is from two to three times as strong per square inch, and its elongation is also somewhat higher than the bearing metal alloy.

The third variable which enters into wear, as I look at it, is what may perhaps be termed the "granular structure of the metal." This may, perhaps, best be illustrated by saying that, of two metals which have the same tensile strength and the same elongation, the one which is finer in granular structure will wear the slower. This, we think, will be evident by returning to our conception of what wear is—namely, the tearing off of minute particles from the worn body. If, now, at each rupture of a particle of metal, the particle torn off is in one case twice as large as in the other, the wear will be twice as rapid, and we assume that, other things being equal, the granular structure represents the size or fineness of the particles torn off at each operation during wear. We have but few experimental data on this point. It is generally believed by those who have had a chance to make observations, that what is known as case-hardened iron wears better than either the wrought iron from which it is made, or than ordinary hammered steel of approximately the same carbon. It has also been observed that case-hardened metal is always characterized by an extremely fine granular structure, as evidenced by the fracture. This, of course, is only an observation, and cannot be taken as proving very much. It is also entirely possible that the influence of what is technically known as "tempering," on wear, may appear in the effect of the temper on the granular structure. The field is, of course, too void of experiment and too little known to warrant anything more than suggestions.

The relation and interaction, so to speak, of the three variables mentioned above is, of course, quite an unknown field. We are inclined to think that the experimental data which have been obtained point clearly to the conclusion that the increase in tensile strength at the expense of elongation is disastrous, as far as wear is concerned. An increase in tensile strength with an increase in elongation would unquestionably, we think, be valuable. The influence of the structure or granular condition may be even more important than either elongation or tensile strength. Of course, the data do not warrant any conclusions, but it seems not at all improbable that the size of the particle torn off, each time one is torn off, may be the most important variable in the rate of wear. It is also not improbable that if some method of measuring the granular structure of metal, and rightly estimating its influence on wear, was known, this information would go far toward explaining many of the anomalous cases of wear which, if my experience is worth anything, are almost universal accompaniments of experiments in this field.

To put the above ideas in very brief shape, I will say, that if anyone wants to design a bearing metal, the first four conditions given above as essential for a good bearing metal must be first met. Then make a metal which will have the highest possible tensile strength, coupled with the highest possible elongation, and add to this the finest possible granular structure, and you will have the best bearing metal that at the present time I know how to recommend.

THE PROPOSED SHIP CANAL BETWEEN NEW YORK AND PHILADELPHIA CONNECTING THE DELAWARE AND RARITAN RIVERS.

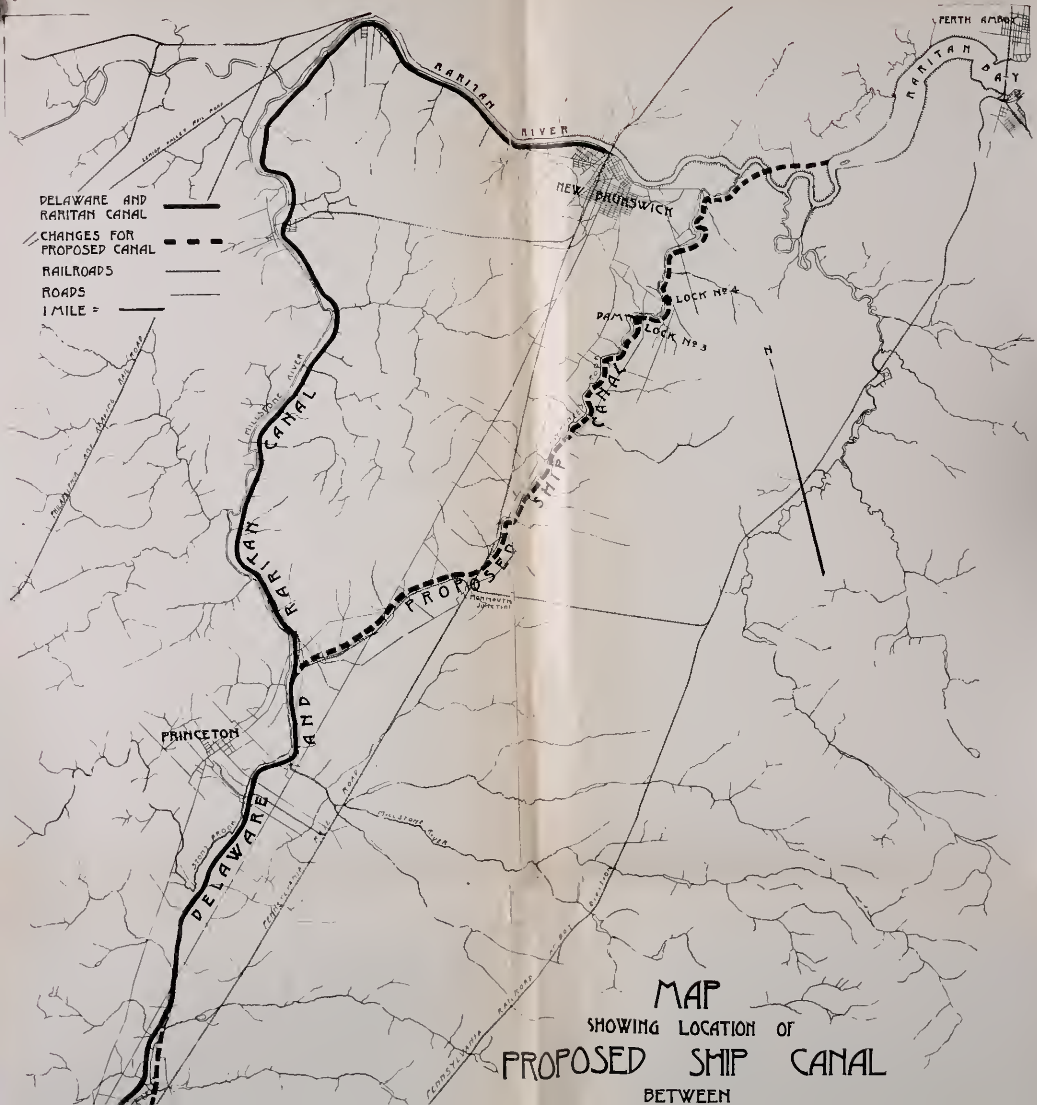
BY PROF. LEWIS M. HAUPT, C. E.

[*Remarks made before the. Franklin Institute at the annual meeting, January 20, 1892.*]

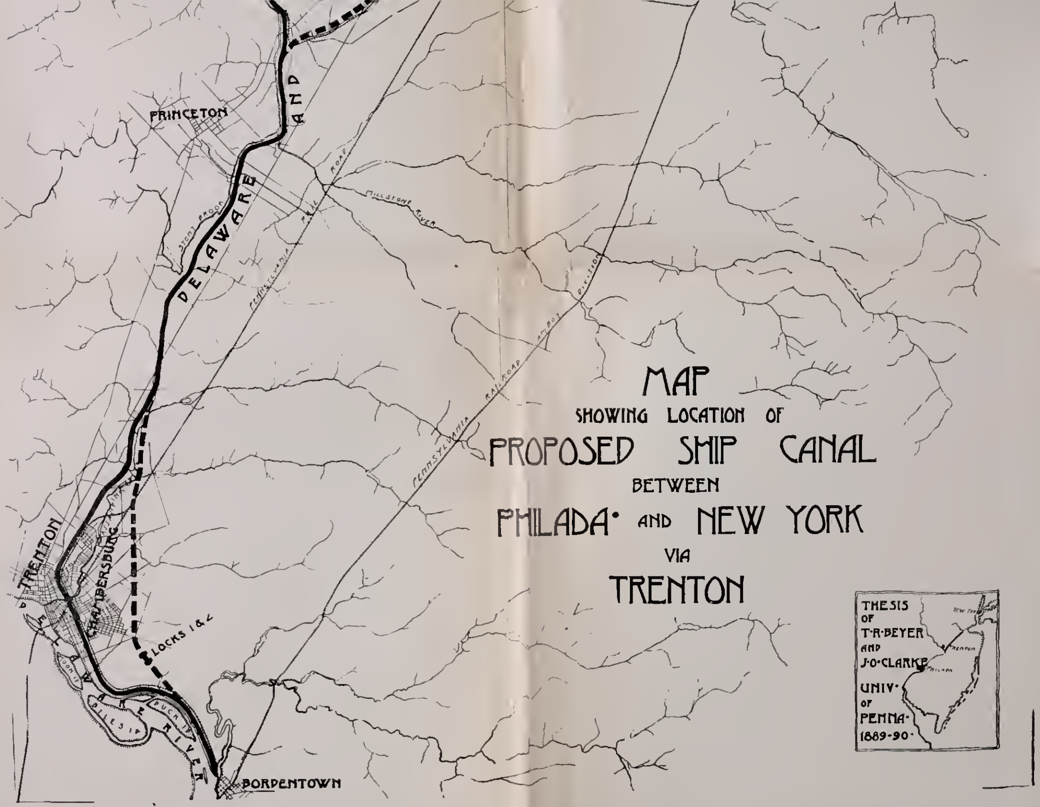
MR. PRESIDENT, LADIES AND GENTLEMEN:

It gives me pleasure to be able to respond to your invitation to speak on the subject of the ship canal across New Jersey, as it is one of great importance to the welfare of this community. It is a cause of regret to us that from various causes Philadelphia has fallen from first to about seventh of our cities in the rank of commerce, but we have the satisfaction of feeling that in manufactures she still retains her preëminence.

If we wish to hold this position in these days of keen rivalry, it behooves us to exert ourselves to cheapen the materials used in our industries and to extend our market



MAP
SHOWING LOCATION OF
PROPOSED SHIP CANAL
BETWEEN



MAP
SHOWING LOCATION OF
PROPOSED SHIP CANAL
BETWEEN
PHILADA· AND NEW YORK
VIA
TRENTON

THESIS
OF
T·R·BEYER
AND
J·O·CLARKE
UNIV·
OF
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1889-90·

range, and it is, therefore, of interest to you as members of this Institute to consider the means whereby these results may be accomplished.

The market price of every article is composed of the cost of production and the cost of transportation. The former is a function of price of raw material and labor; the latter of the rate per mile multiplied by the distance traversed. This latter cost varies with the character of the resistance to be overcome, and is best measured and compared by reducing the load and distance to the unit of the *ton-mile.* Thus, for traffic on a common earth road in good condition the cost of conveying one ton one mile is about twenty cents; on a standard gauge railroad, well equipped, the average is ·928 of a cent or nine and one-quarter mills, although for some articles in bulk the rate is as low as four and one-half mills. On canals of ordinary draught (seven feet) it is less than two mills, and on the great lakes or the ocean it is a small fraction of a mill. Even on the old-time canals, with their boats of limited capacity, the cost is less than *one-half* that by rail, with all the improvements that have been made. The reason is obvious. The mechanical resistances of a rolling train and the ratio of dead to live loads are much greater in the case of the rail than in that of the waterway. Moreover, the capacity of a boat may be increased as the cube of the depth with very little increase of power to propel it. The mere lengthening of the midship section adds but little to the resistance while it greatly adds to the capacity. It is generally conceded that the railway cannot compete with the waterway, and hence the war of extermination. The canals of this country are being bought up and destroyed to enable the railroad to maintain their rates. This does not seem to me to be the best policy for the general good of this country, and it is not that pursued by our foreign competitors. They are now quite active in increasing the draught and capacity of their waterways, and in a few years Canada will have a fourteen-foot navigation from the Great Lakes to tidewater, while we have but seven. This will unquestionably divert the grain trade from our Atlantic ports to those of

Canada, unless it is met by a waterway of equal or greater capacity, which is entirely practicable.

I have been asked of what use would such a canal across New Jersey be to Philadelphia which now has a deep water channel to the sea. In reply, I would say, that it would extend the Erie Canal and its benefits to this port and open to our manufacturers over 16,000 miles of waterways in the great basin of the Mississippi. It would reduce the distance by water to New York harbor from 240 to about sixty miles, would afford an inside and safe passage to eastern, Sound and Hudson River ports; would develop a large population along the entire route, and so benefit the railroads traversing the district. In short, the effect would be to reduce the rate per mile as well as to shorten the distance between the two greatest centres of population on the American continent, or, we may say, in the world; for nowhere else on the globe is it possible by so short and inexpensive a waterway to connect such large populations and so many and valuable interests.

The real import of this reduction in both rate and distance is not fully realized; but it is equivalent in effect to a physical transportation of one or other of the terminals with all its appurtenances through a distance represented by the saving in cost of transportation, just as if a slice of the intervening earth were cut out and the two places brought that much closer together. It enables the market range of our articles of manufacture to be extended in the same ratio; in other words, if the rate per ton-mile can be reduced to one-half or more as it can be by water, its distance of transport may be more than doubled, and the tributary territory will therefore be expanded fourfold.

These are some of the great benefits to be conferred by the construction of this ship canal. Manchester, in England, is expending over $60,000,000 in a twenty-six-foot canal thirty-five and one-half miles long, merely to avoid the terminal and wharf charges of Liverpool, although there are already several canals and railroads connecting it with the sea; and should not we be amply justified in expending a small fraction of this sum to secure results of so much greater magnitude?

I will not detain you to listen to the great importance to the nation of this link in the Atlantic coast waterway for defensive and strategic purposes. Suffice it to say, that it will treble the efficiency of our Navy and be worth many times its cost in saving expense for an otherwise larger armament and the cost of maintaining it,

The route proposed, as revealed by the topographic charts of New Jersey, is shown upon the accompanying map. It is but 33·75 miles in length, and will follow for about eleven miles the route of the existing Delaware and Raritan Canal. The summit level will be 50 feet above tide, and will be reached probably by two locks at either end of 25 feet lift each. These, with the two tidal locks, will make six in all. The cube of material to be removed to give a prism 90 feet wide at bottom, 150 at surface and 20 feet depth of water will be about 26,500,000 yards. The drainage basin tributary to the summit level embraces 301 square miles, and the highest point on the profile is but 76 feet above mean low water.

The physical conditions are believed to be unusually favorable for the enterprise, which is estimated to cost but $12,500,000.

Thanking you for your kind attention, I trust you will find the subject of sufficient moment to engage your earnest coöperation and support.

THE DEVELOPMENT OF SPIRAL WELD TUBE MACHINERY,

BY GEO. ROSS GREEN.

The following account of the development of spiral weld tube machinery may prove of interest to many engineers, especially those who have investigated new and unexplored fields of engineering.

During some nine or ten years prior to 1887, Mr. John B. Root experimented upon spirally welded tubes. The art of welding gun barrels with a helical seam extends back to the beginning of fire-arms; but in the gun barrel the whole body of metal is brought to the welding heat, while in the spirally welded tube the metal at or near the edge only is heated so high, the main part of the skelp remaining practically as it left the rolls. Mr. Root's patent is based upon this condition.

At the time of his death, December, 1886, Mr. Root had completed the machine shown in *Figs. 1, 2, 3, 4*, and had succeeded in making a few pieces of pipe, the longest being twelve feet, of eight-inch, which was never duplicated. This pipe, like the others, leaked badly when tested with water to a few pounds pressure only.

The operation of this machine is as follows: The driving pulley *F* is keyed to a small shaft, which passes through the hollow cast-iron shaft *V*, and has upon its end two eccentrics, which, by means of links, give oscillating motions to the two rock arms *C*. These are pivoted at one end of the shaft *V*, and upon the outward ends of the rock arms are fastened, forming jaws or dies with curved faces, which are expected firmly to grip the skelp and bend it a small amount, depending upon the diameter of the pipe which is to be formed. These dies were made of cast iron, firmly bolted to the rock arms, and were provided with water passages, either cored or bored in them, to allow for a circulation of water in order to keep them cool. Should the driv-

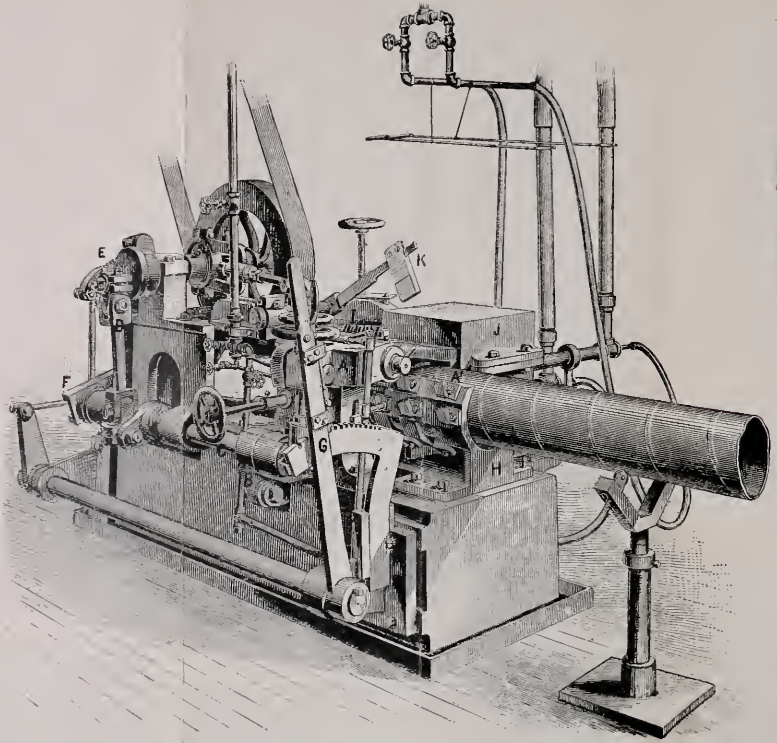

Fig. 6.

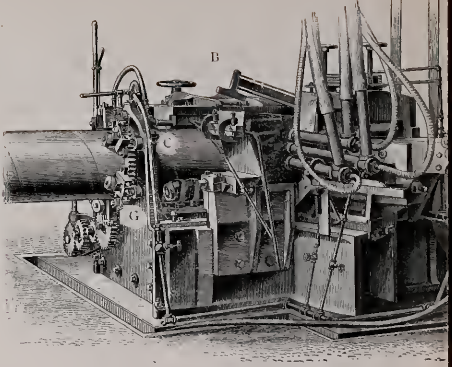

Fig. 9.

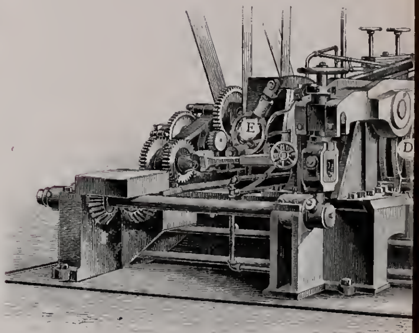

Fig. 7.

Spiral-weld Tube Machiner

(*Green.*)

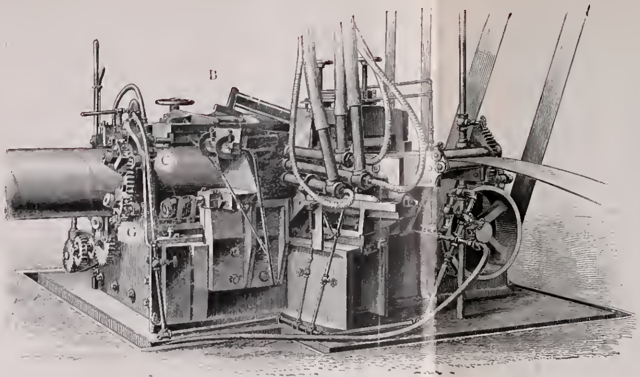

FIG. 9.

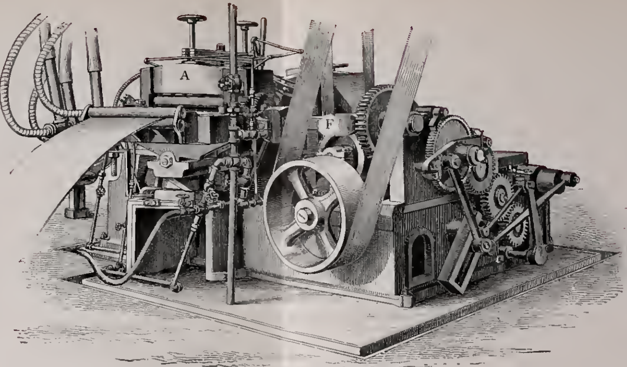

FIG. 8.

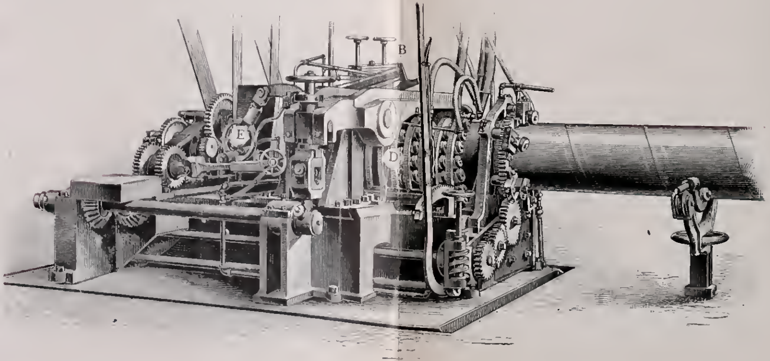

FIG. 7.

SPIRAL-WELD TUBE MACHINERY.

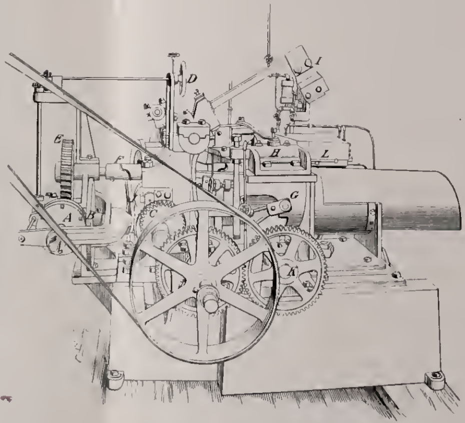

FIG. 5.

ing pulley now be revolved, the rock arms would oscillate to and from each other in one plane. In order, however, to secure a "feed," the rock arms were given a helical motion, which was secured as follows:

Upon the back end of the shaft *V* was keyed an arm *L'* which was connected with the link device, shown in *Fig. 4*, by the connecting rod *M*. This link *I* was pivoted at the left-hand end, and was given motion by means of an eccentric secured to the pulley shaft. By revolving the shaft C_2 the connecting rod *M'* could be shifted to any point of the links and any desired amount of circular movement, within limits, could thus be imparted to the shaft *V*. The forward component was obtained by the mechanism shown at *Q'*. The slide block *P'* is so connected with the shaft *V* that as it slides in the guides *Q'* an end movement is thus given to the shaft *V*. The angle of the guides is set to correspond with the angle of the pipe being made.

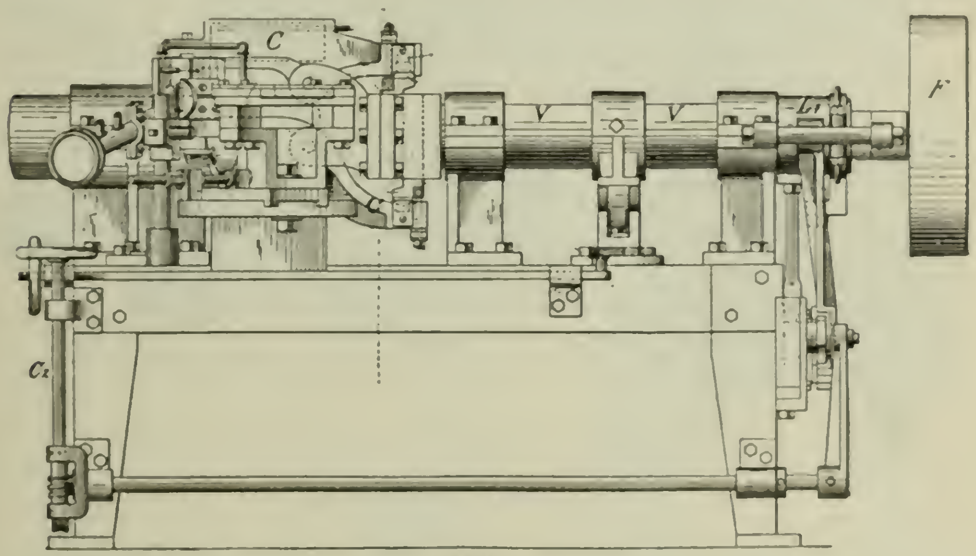

FIG. 1

The machine is so adjusted that when the dies clamp the skelp, the rock arms begin the helical movement, and the mechanism recovers its original position while the dies are separated. The skelp *A* is guided in a suitable table *E*, and the angle is set to give about one-half "lap" to the edges.

The fire-brick lined furnace K_2 is so arranged that one edge of the entering skelp passes into it through a slot in the side for that purpose, and the opposite edge (which has by this time been formed into a cylinder) passes into the flame between the front of the furnace and the fire-brick lined "lip" O_2, *Fig. 3*, secured to the furnace. Both edges are thus simultaneously heated to the welding point, and are hammer welded as they emerge from the furnace. The hammer mechanism is not shown upon the drawings; but it consisted of two hammers, one inside the tube and one outside, which met exactly on the line of weld.

The tube *B* shows a burner which passes into the furnace. The pipe mould *D* is a hollow cylinder made in halves and bored out to fit the tube. This is expected to guide the metal, and keep the pipe of a uniform diameter.

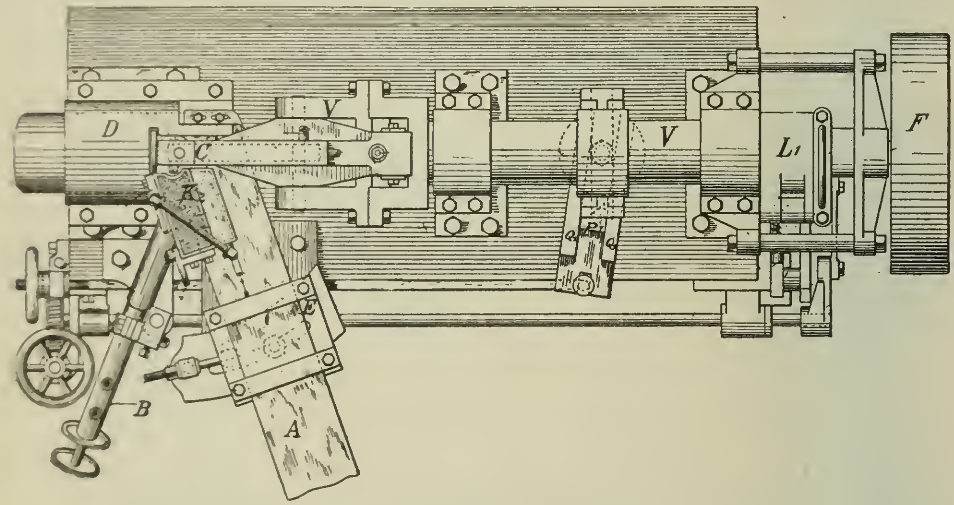

FIG. 2.

This machine was never successful, and among its defects may be mentioned the following:

(1) The general designs and peculiar motions did not permit of making the parts strong enough to bend any but the thinner gauges of skelp.

(2) The feed was entirely too weak to be of practical value. The dies not only were expected to bend the entering metal, and feed forward the tube already formed, and draw in the straight skelp, but were also required to straighten out any inequalities made in the pipe by the hammers. As the weld was much thicker than any other point, the main strength of the dies was expended at this

point, which being in a semi-plastic condition allowed the jaws to slip when any extra force was required. The tendency of the pipe was to enlarge, and this it would do until the friction against the furnace and pipe mould was greater than the strength of the feed; then the pipe would stick and a hole was burned in the skelp. As a rule, not more than four feet of pipe could be made before this point was reached. I have been able, by pulling on the entering skelp, to overcome the strength of the feed.

(3) Adjustment for different thicknesses of skelp were difficult and tedious to make, as the back ends of the dies would grip the metal before the front ends, unless properly arranged.

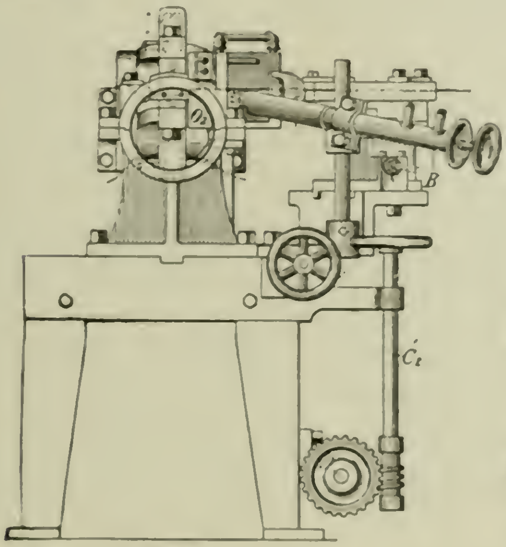

FIG. 3.

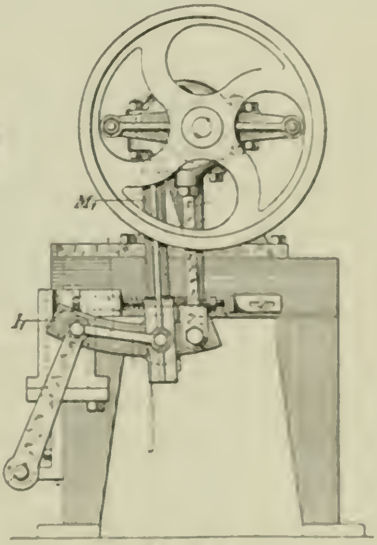

FIG. 4.

(4) The axles of all pipes were the same, and to change from one size to another was a long and unsatisfactory operation, as it required new dies and new hammers, both of which met the pipe at its topmost point.

The Spiral Weld Tube Company was organized about the time of Mr. Root's death, and as he had left no data of value, Mr. Thomas S. Crane, who had examined the machine with the inventor, was engaged to design a new machine, which is shown in *Fig. 5*.

For the clumsy jaws having the helical motion, Mr. Crane substituted feed rolls on the skelp table, which were controlled by a friction device *A B* in the rear of the machine. This consisted of an iron plate *B*, upon which was fastened a sheet of leather, and this plate was given an intermittent motion through the oval gears *C*. *A* was a friction wheel rubbing against *B*, and so arranged that it could be moved to or from the centre by turning the hand wheel *D*. Upon the same shaft as *A* is a worm engaging the worm wheel *E*, and this rotated the feed rolls by means of a shaft, upon which are universal joints *F*.

The pipe mould *G* was a casting bored out to fit the pipe, as in Mr. Root's machine, and upon one side was arranged the fixed former *H*, upon which was fastened a die extending about three-quarters across the skelp. The lower die was mounted upon a movable anvil (pivoted at *J*) raised by a cam on the shaft *K*. The hammer *I* moved in unison with the anvil, and struck it when at its highest point. The machine was adjusted to force the anvil die against the die on *H*, and thus bend the skelp as Mr. Root had done with his oscillating rock arms. *L* shows the furnace, which was cooled by boring holes along the edges and properly connecting them with pipes, as in Mr. Root's machine, through which a constant stream of water was passed. This machine reached the company about three weeks after I became connected with it, and with the exception of some designing by Mr. Crane on the machine, shown in *Fig. 6*, all subsequent additions and improvements have been my own.

No pipe could be made on the machine shown in *Fig. 5*. Upon starting up, the friction discs driving the feed rolls were found to possess insufficient power to force forward the pipe. They would slip in spite of every endeavor to improve them, and were replaced by a positive ratchet mechanism, which was found to answer admirably.

A cylinder could be formed of the cold skelp; but as soon as heat was applied and the edges united the pipe would bind so tightly in the pipe mould that it was necessary to split the pipe longitudinally with a cold chisel to remove it. After several efforts to overcome this, the pipe mould, as shown, was thrown in the scrap and a new one, one inch larger in diameter, was cast to take its place.

Through the shell of the latter, anti-friction rolls (to support the pipe) extended, secured in suitable frames, which were bolted to the pipe mould (see *Fig. 6*).

It was impossible for dies "crimping" but three-quarters of the skelp to form a cylinder, and new dies were arranged double the length of the others. An effort had been made to cause the hammer to take the place of this extension of the dies by bolting to it a curved block, as shown in *Fig. 5*; but this was found to be worthless. The machine was now tried, and a few feet of pipe were made upon it—the longest perfect piece being about four or five feet.

This machine had been so radically changed that it was decided to throw it in the scrap, which was accordingly done and another machine, shown in *Fig. 6*, was built to take its place.

I found the fixed upper die in *Fig. 5* was a great disadvantage, as the friction against it was enormous; and it was therefore arranged to have an oscillating movement (see *A*, *Fig. 6*). The method of mounting this crimper was Mr. Crane's, and he has arranged the axis parallel with the axis of the pipe, which renders it an easy matter to adjust it for different thicknesses of skelp.

The die fastened securely to the crimper *A* is shown at *A′*. The anvil was raised vertically in suitable guides, which cannot be seen in the figure, and the motion was secured by means of a wedge, actuated by the rock arm *B*.

Motion is imparted to the rock shaft *C* by means of the universal joint connecting rod *D*. The link for driving the ratchet *E* is shown at *F*, and the position of the slide block is regulated by the hand-lever *G*.

The pipe mould is shown at *H* with a number of roll frames fastened to it. The corrugated friction feed rolls are shown at *I*, the furnace at *J*, and the hammer at *K*. By arranging a flat place on the top of the wedge which raised the anvil, the latter reached its highest point and dwelt there for a small interval of time, during which both the die *A* and the hammer *K* had performed their functions. The ratchet was adjusted to feed forward the pipe only when the anvil was down, and the die *A′* and the hammer *K* raised.

In order to cool the hammer a water pipe was arranged to throw a small stream against it when at its highest point.

This machine had but one defect; no pipe could be made upon it; *i. e.*, no more than on Mr. Root's machine. It corrected nearly all the defects found in the latter, but it also introduced others which Mr. Root had not encountered.

Mr. Root had run his machine but a few minutes at a time. Efforts were now made to run this machine steadily, but with most discouraging results. The anvil was continually expanding and binding in its guides, so that the belt could not drive the machine. The horn of the anvil and also the dies were continually burning and warping out of line; the hammer would heat to bright redness in three or four minutes; the furnace would crack and allow the water to escape into the fire space, where it was converted into steam, and welding was therefore impossible; and the pipe itself was so corrugated by the hammer and the rolls in the pipe mould that most of it went to the scrap pile. The pressure of the pipe against these rolls was enormous, and they were continually being forced or skewed out of place. The feed rolls were not powerful enough to drive the skelp and pipe forward, and whenever the pipe stuck—which happened with almost every piece—it was necessary to remove the furnace in order to loosen it. To do this required the detachment of the casting holding the fire-brick "lip," which was bolted to the furnace, and as there was practically no clearance at this point and all parts were exceedingly hot, this was by no means an easy operation, and it usually took from one to five hours in order to repair the machine after every such mishap.

At this juncture two ideas occurred to me, and from their introduction may be dated the successful manufacture of these tubes.

First, if the anvil was made stationary the tendency of the pipe to rise from it would prevent binding, and the heating could be done quite as well. Also the "lip" could be secured to the side of the stationary anvil, which would render the removal of the furnace an operation of a few minutes only.

The second idea was to make the pipe moulds in sections having inclined seats upon them, thus rendering it a simple operation, by the use of jigs, to set the rolls securely at the mathematical angles.

This was the end aimed at, but never attained in my other pipe mould. These guide blocks thus formed cost much less than the old pipe mould. The anvil was cored out for a water space, the hammer was properly water cooled and its speed doubled, and the feed rolls were geared together.

I also found much difficulty with the dies. It is necessary in order to form these tubes that the machine should be in good alignment. The dies for 6, 8 and 10-inch pipe are 17 inches long, and for 12 to 24-inch pipe about 37 inches long, and these were necessarily so arranged that an intense blowpipe flame played upon them continually at one point. If made of cast iron they would heat to redness in a few minutes. If cooled by having holes bored in them they would crack and allow the water to spirt through the holes. If made of cast steel and water cooled they would warp in a very short time. If made of wrought iron they would do the same, though not so soon. To bore these out for the water passages was a very expensive operation. This difficulty was solved by casting one-half inch water pipes in the dies and dressing them afterwards. It was also found that fastening the upper die solidly to the "crimper" was not advantageous, and a seven-eighths inch steel rod was half set in the "crimper" and riveted through, and the die was grooved out to fit this rod and secured to it loosely, thus facilitating its seating upon the pipe.

The furnace also had a small pipe cast along the edges next the fire, and the furnace was given a shape different from that of Mr. Root's. Two burners were arranged to enter it, and the proportions of gas and air were experimented with in order to get a reducing flame. As soon as these improvements were put upon the machine it was again tried, and a thirty-two-foot length of 10-inch pipe perfectly straight was made without hitch or trouble. A few days' running showed the machine to be too weak, and a new machine, shown in *Figs. 7, 8* and *9*, was built. In this machine all the improvements mentioned above were incorporated, and also an extra set of feed rolls was mounted on the skelp table. In the previous machine the feed roll housing was fastened to one side only, and overhung the skelp. In addition to that an extra set of feed rolls, shown at *A*, was arranged with bearings on both sides of the table, which materially assisted in the feeding of the large pipe. The hammer *B* was forged of machinery steel, and water pipes were conducted to it as shown. At *C* can be seen the pipes for cooling the top die; at *D* the guide blocks with the rolls mounted upon them; at *E* the hammer connecting rod with buffer stuffing boxes to regulate the blow, which must be light and rapid; at *F* the universal joints on the shaft for driving the feed rolls; at *G* a forward feed device consisting of a ring revolving in a suitable frame with the rolls set at the reverse angle from the guide blocks. These rolls were mounted on blocks, which, by means of springs, allow for any inequalities in the tube. This device is practically a left-hand nut, and it is exceedingly powerful, though it is found that the main feed rolls as a rule are able to feed the pipe alone.

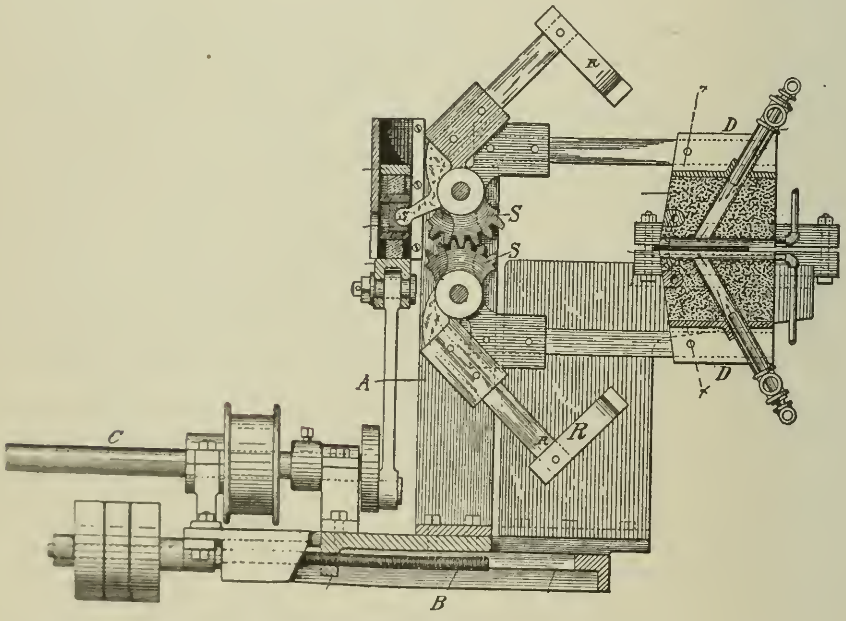

FIG. 10.

Over 800 feet of perfect six-inch pipe have been turned out upon the new machine in ten hours. This is nearly double the amount originally estimated.

Fig. 10 shows the cross welder constructed by Mr. Root, and *Fig. 11* our present one. In *Fig. 10* a suitable frame *A* is moved backwards and forwards by means of the screw *B*. Mounted on the frame are the two hammers *R*, which are geared together by the segments *S S*, the revolution of the hammer shaft *B* causing the hammers to oscillate to and from each other and meet on the line of weld of the straight skelp, which is clamped on each side of the fire-brick lined furnace *D*.

This machine had no method of varying the feed, and the new cross welder, shown in *Fig. 11*, was built, which was run in connection with an Evans friction cone counter shaft, so arranged that the return motion is rapid and the speed constant, while the forward movement can be varied at will.

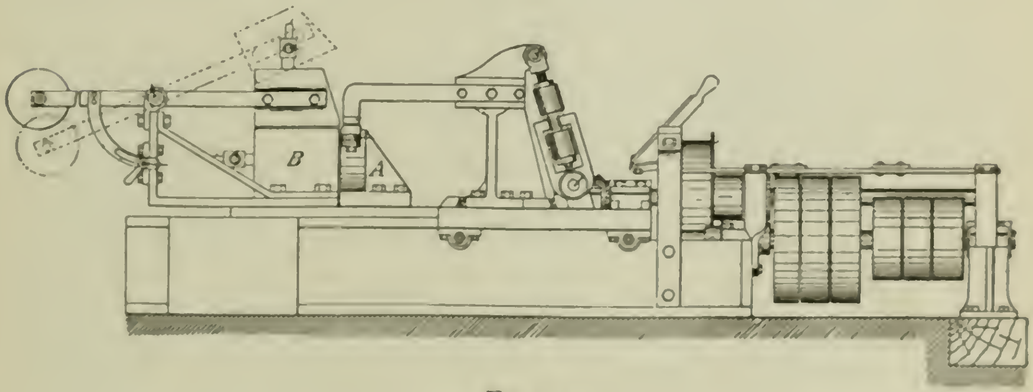

FIG. 11.

The stationary anvil *A* and the furnace *B* are provided, and this machine is able to handle heavy gauges of skelp rapidly and easily.

In these machines one of the most serious problems has been the gas and furnace problem. To continuously heat two edges of a light metal to the welding point, with not more than a foot in the flame at any one time, and to feed this through at the rate of from twenty to forty inches a minute and weld it, is a problem which must be seen to be thoroughly appreciated. Directing the burners a one-half inch higher or lower will often make the difference between success and failure. The distance of the burner from the weld must also be nicely adjusted—if too close an oxidizing flame may be the result, and if too far away the proper heat will not be secured, both of which will prevent welding. Were there but one edge to be heated the matter would be comparatively simple; but when it is considered that there are two edges and the metal is often no thicker than the sixteenth of an inch, it can readily be appreciated how difficult and delicate is the operation, and it was this problem, as well as the machine, that the inventor bequeathed us to solve in a practical and profitable way.

PHILADELPHIA AS A SEAPORT.*

By Capt. F. A. Mahan, Corps of Engineers, U.S.A.

When I was invited to speak on this subject this evening, I imagined that I should have difficulty in filling up the time which these lectures usually occupy. I find, on the contrary, that there are so many matters which have a close bearing upon it, that my difficulty has been to keep within the time which you are willing to give to me. Any one who studies the case carefully will soon find that the plan of improvement is almost the smallest portion of it. Inland transportation by rail and water, financial questions, politico-economical considerations have features to be examined, and to treat of all of them would need the services of lecturers for a season. Still they are not only germane to the cause, but they are of vital importance, and the objections raised by their study must be met before work can be put on a fair and sure basis. As these cannot all be discussed to-night, I shall only touch on some of them lightly in speaking of

PHILADELPHIA AS A SEAPORT.

Philadelphia, the third city of the United States as regards population, the first or second as regards manufactures, is situated on the right bank of the Delaware River, at a distance of about 100 miles from the ocean. Connected with the interior of the country, as it is, by means of three great railway systems we should expect to find it the centre of an extensive trade by sea. We all know that this is not the case.

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* A lecture delivered before the Franklin Institute.

What are the requirements of a great seaport?

(1) Vessels must be able to come in and go out at all times loaded to their full capacity.

(2) Ready means must be at hand whereby one cargo may be removed and the next one stored.

(3) There must be plenty of space whereon goods arriving or going out may be placed temporarily after discharge or before shipment.

(4) Transportation to and from the interior of the country must be supplied, as a city produces nothing. It may transform what is produced elsewhere, but it produces nothing.

(5) Opportunities for having vessels trading at the port repaired must be provided, and they must be such that work can be done at reasonable rates.

Examination of the above requirements shows that they all have one object in view: to prevent loss of time. There is no truer saying in our language than "Time is money." To explain the application of the above requirements let us take the case of a ship costing (say) $300,000, and assume that she is expected to net her owners six per cent. on the investment. This means $18,000 a year, or about $50 a day. In order to earn this a certain amount of freight must be carried in the course of a year; in other words, a certain number of voyages must be made. In the length of the voyage must be included not only the time at sea, but also the time of discharging one cargo and taking in another, the time of removing the former from and delivering the latter at the wharf, the time required to go from the open sea to the wharves and the time to return.

Let us suppose further that under the natural conditions she is able to make six round trips a year to the home port from the foreign port. Suppose now that the foreign port makes improvements whereby the time needed between the open sea and the wharves is reduced one day in each direction, and that the time required to discharge and receive cargo be reduced from two weeks to one, we have a clear gain on each voyage of nine days. On the six round trips there is a gain of fifty-four days, or very nearly an additional trip in the course of the year. In other words, the income from the investment will amount to seven per cent. nearly instead of six. If a port then shows that by its improvements or advantages, vessels can make their voyages with a minimum loss of time, that is the port, all else being equal, which will be most frequented.

Let us examine the port of Philadelphia in regard to the above requirements.

In order that vessels may be able to come in and go out at all times, loaded to their full capacity, two things are required: (1) The waterway must be ample; (2) it must be clearly defined. A reference to the map shows the waterway, and the method of defining it. A description of Delaware Bay and river, as they are found by a vessel coming from sea, gives us first a break eleven and one-half miles wide in the shore line. This break is the mouth of the bay. Before entering there are shoals to be avoided. Those lying near the New Jersey end of the imaginary line joining Cape May with Cape Henlopen, are McCries', Epps', North, Middle and South Shoals, Mummy and Round Shoals. The last two are on the bay side of the line. Just off Cape Henlopen is the Hen and Chickens' Shoal. Between these there is a channel of generous width and ample depth so that vessels drawing thirty feet may enter the bay at any tide, and go up to a point half-way from Ship John Shoal light to Port Penn.

After entering the bay the channel is very straight, and is well marked by means of lights for night travel and by day-marks and buoys for day trips.

After passing the light-house at Ship John Shoal, a vessel runs straight on the range indicated by the two lights at Port Penn. A little above the front light of the Port Penn range is the Reedy Island light. This light has a red cut, and so soon as a vessel enters the red, her course is changed to the right and the Finn's Point range is taken up and held until the New Castle range is found. This range is followed until the vessel enters the red rays of the Finn's Point range rear light, when the course is again changed to the right to the Deep Water Point range. Hence the vessel follows the Cherry Island Flats, Schooner Ledge, Tinicum Island and Fort Mifflin Bar Cut ranges up to what is called the Horseshoe, a curve in the river just above the mouth of the Schuylkill. The ranges here are indicated by limits shown by the lights of the E. and W. groups.

It has now been shown how vessels reach Philadelphia. It is not possible for vessels of the largest size to come up the river for the reason that the depth of water is insufficient at some points. The rise of the tide is, on an average, about six feet. Vessels to be safely and easily handled should have a clear foot and one-half or two feet underneath them. There are places in the river below the city where the depth at low water does not exceed twenty-one or twenty-two feet. Add to this six feet for rise of tide, and we get twenty-seven to twenty-eight feet actual depth of water but only twenty-six or twenty-six and one-half feet available depth.

The formation of these obstructions or bars takes place usually down-stream. It is the result of the action of the various forces developed by tides, winds, rains and passing objects.

Beginning at Bridesburg we find a good channel with twenty to thirty feet of water until we reach Fisher's Point, a little below which is Five-mile Bar, a shoal which starts from the north shore of the river between Bridesburg and Richmond and makes southwardly and westwardly to the head of Petty's Island, obstructing both the channels about the island. The channel north of Petty's Island, between it and the city, is good and has plenty of water.

To cut away the bar a Board of Engineer officers recommended, in 1885, the construction of a dyke from Fisher's Point toward the head of Petty's Island. This dyke was built 3,000 feet long in 1886 with its top at the level of mean low water. In 1888 it was seen that to accomplish its work the dyke should be lengthened 1,000 feet and should have its top raised to eight feet above low water. This change caused a marked gain in the action of the dyke and an increase in the depth of water on the bar from eight to eleven and one-half feet, with a breadth of 500 feet, at low water.

Coming down stream we find plenty of water all along the city front until we go below the mouth of the Schuylkill River.

Lack of depth is not the only obstruction to the free use of a stream. Surface room is needed; in other words, width of channel, so that vessels may pass each other, and, when necessary, have space in which to turn around. This space is seriously lacking in front of the city. It exists from above Petty's Island to the lower end of Smith's Island. Between these two islands the river makes a bend of 90°, passing from a westwardly to a southwardly course. The bar which began above Petty's Island continues downstream and is finally lost below Smith's Island. The channel between these islands and the New Jersey shore is too shoal for deep draught vessels.

For a long time it has been recognized that these islands are greatly in the way. Much time and thought has been given to what is best to be done for the good of the harbor. The matter was referred to a Board of Engineer officers in the spring of 1888 and they recommended the removal of Smith's and Windmill Islands and a slice of Petty's Island, and the establishment of two lines as the boundaries beyond which the ends of the piers on the two sides of the river should not extend. The price of the two small islands and the slice of the larger having been fixed, it was paid by contributions from the United States, the State of Pennsylvania and the city. An appropriation for beginning the removal of these obstructions is contained in the last River and Harbor Bill, and specifications for doing the work are now under preparation by my colleague, Major C. W. Raymond, Corps of Engineers, who is in charge of the improvement of the Delaware River.

Continuing our way down the river we come to what is known as the Horseshoe, in which the main obstruction is the winter's ice. This is kept from blocking the river by ice-boats, which are very powerful tugs especially fitted out for the purpose of breaking up the ice so that it may float off in small chunks.

Beyond the mouth of the Schuylkill we find two deep channels, separated by the Fort Mifflin Bar, which takes its name from the near-at-hand Fort Mifflin, one of the old-time fortifications of the city. Before 1873 this bar had not more than seventeen feet of water over it. In that year dredging was begun in order to deepen the water, but on account of the position of the cut it silted up again very soon. In 1878 the direction of the cut was changed and it was dredged to a depth of twenty-six feet and a width of 500 feet. This depth was increased by scour to twenty-eight and thirty feet, but it did not last long as we find that it had diminished to twenty-four feet in 1880, and to twenty-two feet in 1881; the width had also been reduced. In 1883 the attempt was renewed with no better results. The Board of Engineers of 1885 recommended the construction of a dyke from Hog Island to Maiden Island, and extended, perhaps, to Tinicum Island; the dyke to be built up gradually to the level of mean low water. This dyke was begun in 1885 and finished to Maiden Island in 1888. It is 7,000 feet long and made of rip-rap laid on brush mattresses. The object of this dyke was to deflect the main part of the water which flowed between Tinicum Island and the Pennsylvania shore into the better channel east of the island. In order to hasten the deepening of the channel and to see if the dyke could maintain it a cut was dredged during October and November of 1888, 250 feet wide, with a least depth of twenty-six feet at the sides and twenty-eight feet at the middle. Surveys made from time to time show that up to May, 1890, a gradual shoaling went on, so that in that month only 25·6 feet was found. But the dyke has had a great influence in that neighborhood, as the depth of water on the shoal has increased from one to three feet over a space 8,000 feet long and 1,200 feet wide. Built to the level of low water only, the dyke could not maintain a channel 600 feet wide and 26 feet deep. In accordance with the experience had at Fisher's Point, the up-stream half of the dyke will probably be raised to two feet above mean high water. It is possible that an auxiliary dyke may have to be built out of the New Jersey shore.

Continuing our trip down the river we come to Schooner Ledge in the middle of the channel between Chester and Marcus Hook. This obstruction is a ledge of rock over which, in 1879, there was a narrow channel twenty-four feet deep, while close by it were points of rock standing under eighteen or nineteen feet of water. Inasmuch as blasting under water is more difficult and more expensive than mere dredging, the opening of a channel here has cost much, but when opened it stays. A recent survey shows that by re-adjusting the range lines a channel 1,600 feet wide and 26 feet deep can be had at much less expense than supposed.

Next beyond Schooner Ledge we find the Cherry Island Flats, extending from about Edgemoor to a little below the mouth of Christiana Creek, on which is situated the busy little town of Wilmington. In 1879 this shoal was two miles long, with only seventeen to twenty-two feet of water on it. Dredging was begun during the years 1879–80, and has been continued steadily since then. The channel has now a depth of twenty-six feet and seems to be permanent.

A little below New Castle the river suddenly widens and at the same time makes a sharp bend, changing its direction about 65°. The change of direction from the Deepwater Point range to the New Castle range is very gradual along a curve of which the ends are defined by the red sector of the Finn's Point range rear light. About half a mile above the upper radius of the sector the shoal begins to have less than eighteen feet of water at low tide. Following the bend of the river the shoal gradually gains height and finally develops as Pea Patch Island, on which stands Fort Delaware, another of the old-time defences of Philadelphia. This shoal is known as Bulkhead Shoal, about the most troublesome place on the river. Vessels were reported in 1880, 1881, 1882 as having constant delay there, running aground and having to wait for high water. Dredging had been tried there, but with almost no success.

It will be noticed by the positions of the four-fathom curve above and below the shoal that there are apparently two channels, one formed by the ebb and the other by the flood tide. The ebb channel is the one to the eastward, and it is constantly shifting a little more to the east. The flood or west channel has a motion to westward. They are thus moving apart.

To improve this shoal two dykes are proposed, their position and extent being determined by the conditions: (1) To deflect the currents on the bar and make them aid in getting and keeping the desired depth; (2) to check the hurtful changes now in progress; (3) to connect the deep water above and below the bar by a channel having a direction convenient for navigation. One of these dykes is to begin at the head of Pea Patch Island and extend upstream. Its middle and lower parts are intended to train the flood currents on the bar and prevent the westward movement of the flood channel, while the upper is to catch part of the ebb down the Delaware channel and add it to the current from the east dyke, which starts from the New Jersey shore and passes obliquely across the ebb channel to concentrate the ebb current on the bar. These dykes are not yet under construction. They will be built up to the level of high water.

Below Pea Patch Island a bar extends to a point abreast of where the New Castle and Finn's Point ranges intersect, the water regaining a depth of eighteen to twenty feet. Opposite this spot is found Reedy Point on the Delaware shore, whence begins a bar which gradually rises and forms Reedy Island, at the down-stream end of which is a light having a red sector to indicate the point of turning from the Port Penn to the Finn's Point range.

Just at this turn the water loses its depth and the place is called Baker's Shoal. To correct this place the Board of Engineers of 1885 recommended the construction of a dyke about 25,000 feet long, beginning at the lower end of Reedy Island. Of this dyke nearly 6,000 feet is done. Just below this shoal the river narrows again and the channel depth becomes great until a point about three miles above Bombay Hook Roads is reached. In this stretch of three miles the water is about twenty-one to twenty-two feet deep at low tide, with six feet more when the tide is up. After once reaching Bombay Hook Roads vessels have no further difficulty so far as depth of water is concerned.

The shoals of the river have taken up a good deal of our time, but this has been necessary in order to show that Philadelphia lacks the first essential for a great seaport. The largest vessels cannot come here because there is not sufficient water. In fact I believe that the greatest draught of a vessel leaving the port is twenty-seven and one-half feet. With the present channel the pilot who takes out a vessel so deep in the water must know every foot of the road from the city to the sea better than the majority of my hearers know the floors of their houses; he must have plenty of nerve and keep perfectly cool. With these and no bad luck he may succeed in going through, but there is an element of risk of which few men will care to shoulder the responsibility.

We therefore dismiss the first condition as unfulfilled.

The second condition is that ready means must be at hand whereby one cargo may be removed and the next one stowed.

Let me here call your attention to an important point which, it appears to me, is frequently overlooked in discussing this question. With very, very few exceptions no city is a producer. It may be a manufacturing place gaining its prosperity by transformations, or it may be commercial and find its riches by transhipment from one style of conveyance to another.

Cities on the seashore, and indeed on most navigable highways, partake more or less of both characters, seeing that no matter to what extent mere commercial business is carried on there must also be more or less of manufacturing. In fact, the very necessities of a town must cause the changes in raw material required to meet the wants of the people. As illustrations I may mention Savannah and New

Orleans as essentially commercial cities, while Philadelphia is essentially manufacturing, and New York partakes largely of both sorts, the commercial predominating.

Now, as a city produces nothing, everything must be brought to it, and consequently facilities for handling should be provided. Considering our special case, Philadelphia needs enormous quantities of raw materials. With all her great shipyards, machine shops, woollen and cotton mills and factories of so many sorts that to mention them would require an evening, she does not produce a single initial effect. The ore, the raw cotton, the wool, the wood and the thousand other things which she transforms into articles of use or luxury must every one be brought to her, and not only they but two great elements of change, fire and water, have to come from afar.

In general terms then we may say that the essential feature of a city's existence is labor in some shape or other. Labor is mainly the cause of increase in the value of material. The value of a tree standing in the forest, or of ore buried in the ground is as nothing when compared with the finished products obtained from either. Labor must first be expended to fell the tree or delve the ore. It appears at every turn, and when it ceases to act the material comes to a stop, and there stays.

In a manufacturing city, then, there exists one great part of the increase of value, labor. But labor without material is nought. Material can be brought to labor much more cheaply than the reverse operation can be performed, therefore where the aggregation of labor is there exists the means of transformation. A manufacturing city must have material and that material must be handled. Handling must be done at the lowest possible cost, else the price of the material is unduly increased and, indeed, may be made prohibitory. We may conceive of a vessel-load of coal being discharged by carrying it out in hods on men's shoulders. It would be a very slow process and would add enormously to the price of the fuel. Now, as the cost of the finished article must be kept as low as possible in order to compete to advantage with other places, the cost of handling the material must also be kept at the lowest limit. Machinery, therefore, is necessary, in plenty and of the quickest-acting type.

How ill provided with this machinery are the Philadelphia wharves and piers is patent to him who will look at them. To any one who has seen the splendid equipment of almost all the great foreign seaports this lack in our own is not pleasant to contemplate. To mention only one case I will speak of Antwerp where along the entire length of the quay are found at intervals of about thirty-five feet, nozzles to which movable hydraulic derricks may be attached, and these last are so numerous that, if necessary, it is almost always possible to have two of them working at each hatch of a vessel. This sort of thing struck me everywhere. At London, Liverpool, Marseilles, Genoa, and at other points I found the same equipment of quick-acting machinery made necessary by the sharp competition existing among these ports. In this, as in manufacturing, economy of time and labor is sought. Consequently a machine is used which does not get out of order and which needs no more intelligence to handle it than that which is sufficient to throw a lever. So far as I have been able to learn we may say that the port of Philadelphia is unprovided with ready means of discharging and loading vessels. The second condition is therefore unfulfilled.

The third condition is space for storing cargoes discharged or waiting to be taken on board.

How many piers are there along the water-front of the city where two cargoes of a trans-Atlantic liner could be stored? Not one, I venture say, unless it be in the possession of a railway for its own use. But it has been found in the great foreign ports that it is necessary to have this space, so that the operations of unloading and loading may go on without hitch or hindrance. Where the service is properly organized, no difficulty is encountered in doing this. In some places there are platforms, separated by passages, devoted alternately to incoming and outgoing merchandise. By this arrangement time is saved and an element of expense reduced.

As secondary to the second and third conditions we must have convenience of access for vehicles of all sorts, whether drays, cars or anything else for bringing or taking away freight. These require space in which to move freely. Where the space is not, there we find crowds and jams, hard to handle and sometimes almost impossible to untangle. A very short walk along Delaware Avenue will convince the most sceptical that there is no convenience for transportation. Then, too, how many piers can be reached by cars? When I say reached, I do not mean simply arriving at the root of the pier, but going out on it so that their loads can be transferred direct to the vessel, or *vice versa*.

Contrast this state of affairs with the great spaces along the quays at Genoa or Marseilles or Antwerp or many another foreign port. New York is beginning to wake up to the necessity of space, and at some parts of West Street may be found a width of 100 yards from the bulkhead back to the building line. This is none too much for the free circulation of a large trade.

We may say that the third condition is unfulfilled.

The fourth condition of transportation to and from the interior is fairly well met. Three important lines of railway centre here, and through them any part of the country may be reached. Still, here I think is the greatest drawback to Philadelphia's endeavor to become a great port. She can, without doubt, rival every city on the coast except one, because none of them is much better off than herself, but in the struggle with New York she is greatly handicapped by the Erie Canal. That, after all, is the great secret of New York's success, and only after it was built did New York begin to outrank Philadelphia as a seaport.

I remember some years ago seeing the remark made by a French writer that no seaport could become great without water communication with the interior. This is true within limits. Foreign nations understand this much better than we, and they are constantly adding to their canal systems. A boat can now be sent, in France, from Dunkirk on the North Sea to Marseilles on the Mediterranean and thence to Bordeaux or Havre on the Atlantic.

Belgium is a network of canals, and Germany is studying the subject with many great projects in view. In France the most enlightened development has taken place and canals are constructed on a uniform gauge after the manner of railways. So fully is the value of these navigable highways appreciated, and so well is their function understood, that some of the most powerful railway companies are their enthusiastic financial supporters, realizing that there is much which canals can carry as well as they, and at cheaper rates.

In our own country, unfortunately, there is almost no one to look after the canals.

Mr. Albert Fink, the head of the great railway pooling interests, testified before a Committee of the Senate that water transportation is the one check on railway rates. Compare the cost of transportation of grain from Chicago to New York when the Erie Canal is open and when it is closed. It is to the interest of the railways to close the canals; and to them may be traced the cry that canals are out of date. Legislators are easily influenced by passes over the railways, and canals having nothing to offer, suffer. If the same improvements had been made in canals which have been made in railways, if the same study had been given to them, if the same care had watched over their interests, we should not hear to-day that canals are useless. Even in its present old-time condition the Erie Canal carries in seven months one-third of all the grain going to New York during each year. In other words, the many lines of railway centring in New York, with all their modern improvements, require six months to do what the one old-fashioned canal does in seven. I am convinced that the last chapter on American canals will not be written for many a long day.

But we are not here to discuss canals. Still these few words seem germane to our fourth requisite of interior transportation.

The fifth condition is that vessels trading at the port must have opportunities for making repairs at reasonable rates.

I have not had the time to investigate this subject in Philadelphia, but I do know that in New York no foreign ship will make repairs if they can possibly be put off until the home port is reached. From the little I have heard, however, I should judge that the cost of repairs in Philadelphia is such as to make a vessel try to have them done elsewhere, and, furthermore, the facilities which exist here at the present time are not sufficient for an extended trade.

Having shown to what an extent the port is lacking, let us look around a little and see what can be done to remedy defects.

The policy of the general government is simply to make the path of a vessel clear from the deep sea to the port, or from one port to another along a stream. Under no circumstances has it ever undertaken to improve the commercial facilities of a city so as to simplify any of the operations of unloading or loading cargo. It does take under its charge all the improvements which come under the first condition of a seaport, that vessels must be able to come in and to go out at all times loaded to their full capacity.

We have already seen what has been done at many points along the river and it is likely that work will be continued along these lines for a long time to come.

The many calls made on the treasury, the absurd jealousy of one part of the country as regards the others, the uncertainty of appropriations, are all so many forces retarding the completion of any given work. So long as the press of one city regards the work in its neighborhood as all-important, and denounces all work done elsewhere as robbery, as a political job, as unnecessary to the commercial interest and development of the country, just so long will Congress be hesitating in the matter of appropriations. Then, too, it must be acknowledged that much is included in the appropriations which would better be left out. Members of Congress are but human after all, and so long as the services of any one of them are judged by the amounts of money obtained for his district, just so long must unworthy measures clog the completion of those which are good. Still, these unworthy items are by no means so many, nor do they involve the sums which the outcries of the press would lead us to suppose. Taken as a whole, there is probably no item of expenditure made by the people of these United States which brings in so large a return in increased prosperity for the whole as this same much-abused and roundly-denounced River and Harbor Bill.

There is no doubt that more would be accomplished for the money spent if the people would consent to leave the direction of funds in the hands of disinterested persons who could weigh the merits of each case and determine the early finishing of works of prime importance, leaving the secondary and tertiary ports for later consideration. But the people will not have it so, and the treatment of ports is very often, in respect to funds, inversely as their commercial values.

These points may explain why Government work is generally so slow in completion. They are mentioned here to explain the cause of the great length of time which must probably pass before the works for the improvement of the Delaware are done.

The second, third and fifth conditions must, under our system, belong either to the city or its citizens, but before considering them let us take a look abroad and see what is done at some of the more important points.

A person who has not interested himself in going among the great seaports, and indeed, among many of the smaller ones, can have no idea of the enormous sums of money which have been spent and are now a-spending on the improvement of harbor facilities. The competition between the ports of the countries of Europe is tremendous. Everywhere the works planned and building are almost of stupendous size. Italy, France, Germany, Holland, Belgium and England are spending vast amounts. In some of these States the general government mainly does the work, as in France and Germany; in others, it is divided, the general government taking a part of the load as in Italy, Holland and Belgium, while in England everything is done by private or corporation enterprise with little or no assistance from the State.

Go to London or Liverpool and see the miles of quays and acres of docks built by private capital and learn from them how wise has been this vast expenditure. Think on the Clyde and the Tyne, how from insignificant streams they have become the bearers of a mighty commerce. Again consider Manchester and the titanic work she is pushing through in the shape of a canal thirty-five and one-half miles long which will enable vessels drawing twenty-five feet of water to come to her docks after overcoming an ascent of sixty feet.

That these works are no child's play will be shown by a few figures. Take first the Manchester canal: It is thirty-five and one-half miles long, the minimum width at the bottom is 120 feet for a length of thirty and one-half miles, and 170 feet for the remaining five miles. The average width at the water level is 172 feet. The minimum depth is 26 feet. These figures give a total excavation of 30,000,000 of cubic yards for the trunk of the canal, provided that in no place does the ground along its sides lie higher than the surface of the water. But no consideration is made of the excavation for docks or locks. The water surface of the docks is 133¾ acres, all to be dug out of the earth. Of the locks there are fifteen:

1	600	feet long by	80	feet wide.
4	600	"	65	"
1	600	"	45	"
1	400	"	45	"
1	350	"	50	"
4	350	"	45	"
1	250	"	45	"
1	229	"	42⅔	"
1	150	"	30	"

To carry on this work requires 100 steam excavators, 173 locomotives, 194 steam and other derricks, 182 portable and other steam engines, 209 steam pumps, 6,300 cars, 59 pile-drivers and 223 miles of temporary railway; 16,361 men and boys, and 196 horses are employed. Of coal about 10,000 tons are used every month, and of cement about 8,000 tons or 44,000 barrels of 400 pounds each. I have been unable to find any estimate of the cost of the work, but I am sure that I shall be well within the mark when it is put at $50,000,000.

The relative situation of Manchester and Liverpool is very similar to that existing between Philadelphia and New York. Manchester, like Philadelphia, is essentially a manufacturing place. Liverpool, like New York, is commercial. All of Manchester's business was done through Liverpool, as almost all of Philadelphia's is done through New York. The transportation between Manchester and Liverpool, as between Philadelphia and New York, is mainly by rail. Rail freight charges were oppressive, so the Manchesterians rose and said they would stand that sort of thing no longer; and proceeded to make a canal and to render themselves independent of Liverpool, and to do their own shipping.

Let us turn now to Glasgow and see what she has done with the Clyde, which, in the middle of the last century, was so insignificant a stream that it could be forded twelve miles below the city. From 1770 to June 30, 1890, there had been spent on the improvement of the Clyde $60,000,000 in round numbers. Much material has been scoured from the bed of the river through the agency of dykes, training walls and other works, and in addition to this, over 36,000,000 cubic yards have been removed by dredging. Instead of a petty stream, across which one could almost walk dryshod, there is now a channel through which vessels drawing twenty-four feet can pass at any stage of the tide. It may also be mentioned that the revenues accruing from these enormous expenditures have been most satisfactory, as they amount to $40,000,000 in round numbers, or sixty-six and two-thirds per cent. on the investment, which may be regarded as an excellent interest in a land where the prevailing rate is from three and one-half to four per cent.

[*To be continued.*]

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, February 16, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1892.

Dr. W. H. WAHL, President in the chair.

The Treasurer made the following report for the year 1891:

Cash on hand January 1, 1891,			$97 33
Received:			
By initiation fees,		$18 00	
Dues, 1890,	$6 00		
1891,	138 00		
1892,	2 00		
		146 00	
			164 00
			$261 33
Expended:			
Printing by-laws,		$12 99	
Addressing and postage,		31 50	
Printing for secretary,		18 75	
Envelopes and postage for treasurer,		3 94	
Friedlander's bill,		62 30	
			129 48
Cash on hand January 1, 1892,			$131 85
Outstanding dues, 1890,			$2 00
dues, 1891,			14 00
initiation fees,			2 00
			$18 00

The resignation of Dr. Persifor Frazer was read and accepted.

A number of bills, the contraction of which had already been authorized by the Section, were presented, and on motion it was voted that the Treasurer be authorized to pay them.

The Treasurer also presented a bill for expenses incurred in binding and in preparing for distribution among the members the copies of vol. iii, 1891, of the Proceedings of the Section. The President explained that these expenses properly belonged to the Section rather than to the Institute and on motion the payment of the bill was authorized.

Dr. E. H. Keiser gave an account of an investigation upon the composition of the explosive copper and silver compounds of acetylene. The paper will be published at length subsequently. The results obtained are in brief as follows: When pure acetylene is conducted into an ammoniacal solution of silver nitrate, the yellowish white precipitate which is formed has, when dried, the composition represented by the formula C_2Ag_2. It may in fact be regarded as acetylene in which both hydrogen atoms have been replaced by silver. The formula that has generally been adopted for this substance is $C_2H_2Ag_2O$. But such a compound contains only 83·71 per cent. of silver, whereas in three specimens of the substance prepared by Dr. Keiser the quantity of silver found was 89·32, 89·44 and 89·60 per cent. The formula C_2Ag_2 requires 89·9 per cent. silver. That the compound contains no hydrogen was shown by exploding a weighed quantity of it in a glass tube which had been exhausted with an air-pump; no hydrogen was obtained.

A study of the compound formed by acetylene in ammoniacal cuprous chloride showed that it was similar in composition to the silver compound, although in this case it was much more difficult to obtain the substance perfectly free from water. Analyses showed that the composition of the substance after it had been dried in a vacuum over sulphuric acid, agreed very closely with what would be required by the formula $C_2Cu_2.\frac{1}{2}H_2O$. The investigation will be continued.

The paper was listened to with close attention by the members present, and was followed by a number of questions and comments.

Dr. Bruno Terne followed with a paper, entitled "Notes on Iron in Bone Black." It was of special interest in connection with the application of bone black in sugar refining, and was discussed by the author and Dr. S. C. Hooker, the latter from the standpoint of an expert in sugar refining. Dr. Hooker stated that in cases where the percentage of iron reached a sufficiently high limit, it would be imparted to the sugar solution rather than abstracted from it, and hence such bone black would do harm rather than good. He also stated that sugar itself in solution has the power of dissolving iron, hence a further reason for the importance of eliminating iron in the manufacture of bone black.

Dr. Terne's paper was referred for publication in the *Journal.*

The Section then adjourned.

Wm. C. Day, *Secretary.*

ANALYSIS OF "EGGIO:" A PREPARATION OF THE YOLK OF EGGS.

BY CHARLES S. BOYER.

[*Read at the stated meeting of the Chemical Section, January 19, 1892.*]

About a year ago I had occasion to make several analyses of "eggio"—a preparation of the yolk of eggs. Aside from the researches on pure egg yolk, I was unable to find any published analysis of the commercial product, and it may be of interest to place on record the results of my analysis. The ingredients for which the eggio was examined were water, ash and fatty acids, these being the only constituents of value in the dressing of fine leathers, for which purpose most of it is used.

The method which I used was as follows: Two to four grams of the eggio were dried in a weighed platinum dish for two to four hours at 110° C. and weighed, the loss being regarded as water. In order to facilitate the drying, a weighed quantity of coarse, ignited sand, or small pieces of infusible glass, was spread over the bottom of the dish. This dry residue was then ignited at a red heat and the resulting ash was calculated as mineral matter. The ash was light gray to white in color and was tested qualitatively for lime, but in no case was any found.

For the fatty acids, ten grams of the eggio were placed in a flask of about 350 cc. capacity and 150 cc. of ether poured over it. The flask was then connected with a reflux condenser and heated on a water-bath for two hours, being shaken every now and then to break up the white albuminous mass which collected in the bottom of the flask. The solution in the flask was allowed to cool and 50 cc. of the supernatant liquid removed by a pipette, replaced by 50 cc. of fresh ether, and the flask again heated for one hour, with frequent shaking as before. The flask was then allowed to cool and the clear yellowish liquid drawn off and added to the 50 cc. previously withdrawn. The contents in the flask were twice washed with ether and the ethereal layer added to the first. This ethereal extract was placed in a flask and a portion of the ether distilled off. The solution was then placed in a weighed platinum dish and the remainder of the ether driven off on a water-bath. The residue in the dish was dried in an air-bath at 105° C., to expel any adhering water, and weighed.

The method was tried on a sample of fresh egg yolk and yielded 20·00 per cent. fatty acids, while in König's *Nahrungs- und Genussmittel* the percentage of fatty acids in pure egg yolk is given as 20·3. I, therefore, concluded that the method was sufficiently accurate for technical purposes.

As a result of the analyses of five samples of different lots of eggio by the above method, I obtained the following results:

	I.	*II.*	*III.*	*IV.*	*V.*
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Water, . . .	55·64	56·81 56·06	56·91 56·45 56·79	54·20	53·75 53·62
Ash, ...	11·73 11·80	19·25	9·46 9·47	13·67	16·35
Fatty acids,	14·66	—	—	16·00	15·23

In order to compare these results with those found for pure egg yolk, I give the following analyses, the first from König's *Nahrungs- und Genussmittel* and the second obtained by the writer with the above method.

	I.	*II.*
	Per Cent.	*Per Cent.*
Water, ...	51·8	53·72
Salts, ...	1·0	—
Fatty acids, ...	20·3	20·00

By comparing these values with those above, it is found that commercial eggio contains from two to five per cent. more water, and three and one-half to six per cent. less fatty acid, than are found in pure egg yolk. The salts are sodium salts added in order that the eggio may be preserved from putrefaction.

As soon as time will permit, I hope to be able to communicate the exact composition of the ash of eggio, which I think will be of value in supplementing the above partial analysis of this product.

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, February 2, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty members and visitors.

The minutes of the previous meeting were read and approved.

The Secretary and Treasurer reported the issue of the first volume of the Section's *Proceedings*, and the cash balance on hand in the treasury.

The Committee on Admission reported one election to membership since last meeting, and one nomination was referred to them.

Resignation of membership from Prof. Henry Crew was accepted with regret.

The Chair announced the receipt of the first number of a new and promising French electrical journal, *L'Industrie Électrique*, edited by E. Hospitalier; the unavoidable postponement of Mr. Tesla's lecture in the Institute course, and of his later appearance before the Section; and the time-limit for papers read before the Section, with its possible extension.

Mr. Carl Hering described some details of the plant for power transmission at Niagara, some features of the Frankfort Electrical Exhibition, and Burton's process of electric forging, illustrating his remarks with lantern pictures.

Mr. Wm. S. Aldrich showed the results of some experiments upon the tractive force exerted on the core of a double-coil solenoid.

Prof. Houston's paper on "Cerebro-Radiation" was deferred till next meeting.

Several queries from the Question-Box were answered, and others evoked considerable interesting discussion.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

AN EARLY CONCEPTION OF THE MAGNETIC FIELD.

BY PROF. EDWIN J. HOUSTON.

[*Read at the stated meeting of the Electrical Section, January 5, 1892.*]

It may interest the members of the Electrical Section to know, that as early as 1668, Robert Boyle, the eminent physicist and chemist, published, concerning the magnetic field, exceedingly advanced ideas which closely resembled the modern ideas of magnetic flux and lines of magnetic force.

Boyle's publication, so far before the time of Faraday, shows the exceedingly advanced position he must have occupied at that early date, as a thinker and investigator in physical science.

Boyle was an indefatigable worker, and a voluminous writer, both in the domain of physics and chemistry, as well as in that of medicine. He taught that absolute rest had practically no existence even in bodies in apparent rest, since there existed in such bodies what is called an intestine motion of their particles. He also had original notions of what was called, in his time, effluvia, and it was in connection with these so-called effluvia that he advanced an explanation concerning the magnetic action of the loadstone, which bears a remarkably close resemblance to the modern ideas of a magnetic field and lines of magnetic force.

The quotation referred to is from the second of two essays "Concerning the Unsuccessfulness of Experiments" published in 1668. In these essays he has been pointing out the necessity for care in conducting scientific experiments, and urges, that the failure to experimentally reproduce any natural phenomenon should not necessarily call in question the accuracy of the first observer of such phenomenon, until all the sources of error that might have led to obscuring or vitiating it had been eliminated. In this connection he cites, in a quaint manner, some of the numerous experiments that he had been led to try on the assertion of well-known scientific men, but in which he failed to obtain the results alleged to have been observed. He describes in this connection the magnetization produced by touching a steel knife-blade to the armed pole of a loadstone, as resulting in different polarities according to whether the point of the blade is drawn towards or from the equator of the loadstone.

I will quote Mr. Boyle's remarks in full in this connection:

"If on either of the Extremes or Poles of a good armed Load-stone, you leisurely enough, or divers times, draw the back of a Knife, which has not before receivd any Magnetick influence, you may observe, that if the point of the blade have in this affriction been drawn from the middle or Æquator of the Load-stone towards the Pole of it, it will attract one of the Extremes of an equilibrated Magnetick Needle; but if you take another Knife that has not yet been invigorated, and upon the self-same Extremity or Pole of the Load-stone, thrust the back of the Knife from the Pole towards the Æquator or middle of the Load-stone, you shall find, that the point of the Knife has, by this bare difference of Position in the blade whilst it past upon the Extreme of the Load-stone, acquired so different a Magnetick property, or Polarity, from that which was given to the former Knife by the same Pole of the Load-stone, that it will not attract, but rather seem to repel or drive away that end of the Magnetick Needle which was drawn by the point of the other Knife. And this improbable Experiment not only have we made trial of, by passing slender Irons upon the Extremities of armed Load-stones, the breadth of the whose Steel-caps may make the Experiment somewhat less strange, but we have likewise try'd it by affrictions of such Irons upon the Pole of a naked terella, and we have found it to succeed there likewise. How strange soever it may seem, that the same point or part of the Load-stone should imbue Iron with contrary Properties, barely as they are, during their passing over it, drawn from the Æquator of the Load-stone, or thrust towards it. But whether, and how far this Observation insinuates the operations of Load-stone to be chiefly performed by streams of small particles, which perpetually issuing out of one of its Poles, do wheel about and re-enter at the other; We shall not now examine (though this seem one of the most likely Phænomena we have met with, to hint a probable Magnetical Hypothesis) contenting ourselves to have manifested by what plainly appears, how much influence a circumstance, which none but a Magnetick Philosopher would take notice of, may have on an Experiment."

Mr. Boyle had obtained an insight into the actions which occur during magnetization, far beyond that of his contemporaries. This fact appears to be clearly indicated by the above statement as to what he believed to be the actual operation of the lodestone; namely, that it produced magnetization by means of streams of small particles coming out of one pole and re-entering at the other pole. Change the phraseology but a trifle and leave the ideas as expressed, and we have at this early date a fair idea of the modern notion of magnetic flux.

Boyle's notion seems to have been that when other bodies were brought into this magnetic stream, they became endowed with magnetic properties by the particles or corpuscles forming the stream, passing through them, just as we now explain magnetization by the passage through a magnetizable substance of the lines of magnetic force.

In a later paper, published in 1669, on "The Absolute Rest of Bodies," he asserts that the particles even in exceedingly dense substances that are apparently at rest, are, in reality, in rapid motion. He urges that although such motions cannot be seen, yet they must exist, and cites as a proof of such assertion, the following experiment, which I will give in Mr. Boyle's language:

"I briefly answer (for I would not here repeat what I have elsewhere said on this point) by this clear Experiment, that though your Eye can discern no change in the outward and visible, much less in the more latent and internal Corpuscles of Iron: a vigorous Load-stone by passing along its Axis from one Pole of the Stone to the other, and back again, yet the Texture of the Iron is by that action of the

Load-stone so changed, that it acquires, and then loses those admirable Qualities we call the Attractive and Directive virtue or faculty peculiar to Magnetick Bodies."

And further on, in the same paper, in speaking of the well-known fact that a mass of steel when allowed to stand in an upright position for some time on the earth, is endowed with magnetic properties, he ascribes these properties to the action which the streams of corpuscles exert on it.

"To this purpose I shall only observe to you, that though a Bar of Iron having one of its ends held perpendicularly, and at a fit distance to the Lilly or Northern point of the Mariner's Compass (I mean that which points towards the North), it will, as I elsewhere mention, drive it away towards the East or West: and if this same lower end of the Bar of Iron be put into a contrary posture, it will presently lose its temporary magnetism, as I elsewhere declare. Yet if this Bar be very long kept upright in a Window or other convenient place, then, as some late Magnetickal Writers will tell you, it will have acquired a constant and durable Magnetick power. Which is a phenomenon which makes exceedingly for our present purpose, since it hence appears both that the Air together with the magnetical effluvia of the Earth that it receives in its Pores, is able without outward force to work durable changes in so solid a Body as Iron, and that the motions of the internal Parts, for these are requisite to change the Metal's Texture, are performed with a wonderful slowness, since the Bar must be very long exposed to the air, perhaps before it acquires any durable magnetism at all, but at least before it acquires so vigorous and fixt a magnetism as by this means it may attain to."

In another paper on "The Nature, Properties and Effects of Effluvia," reproduced by Shaw at a later date, in vol. i, p. 411, of the Philosophical Works of the Honourable Robert Boyle, Esq , 1725, Boyle writes as follows:

"To clear this matter, I caused some needles to be hermetically sealed up in glass pipes, which being laid on the surface of the water, whereon they wou'd lightly float, the encluded needles did not only readily answer to the load-stone externally applied, tho' a weak one, but comply'd with it so well that I cou'd easily lead, without touching it, the whole pipe to what part of the surface of the water I pleased. I also found that by applying a better load-stone to the upper part of the seal'd pipe, with a needle in it, I cou'd make the needle leap up from the lower part, as near to the load-stone as the interposed glass wou'd give it leave. But I thought it more considerable to manifest, that the magnetical effluvia, even of such a dull body as the globe of the earth, wou'd also penetrate glass. And this I attempted after the following manner. I took a cylindrical piece of iron, about the bigness of one's little finger, and between half a foot and a foot long; having formerly found that the quantity of unexcited iron forwards its operation upon excited needles; and having hermetically seal'd it up in a glass pipe, but very little longer than it, I suppos'd that if I held it in a perpendicular posture, the magnetical effluvia of the earth, penetrating the glass, wou'd make the lower extreme of the iron answerable to the North Pole; and, therefore, having applied this to that point of the needle, in a dial or sea-compass, which looked towards the North, I presum'd it would drive it away, which accordingly it did. And having, for further trial, inverted the included iron, and held it in a perpendicular posture, just under the same point, that extreme of the iron rod, which before had driven away this point, being, by inversion, become a South Pole, attracted it; from which sudden change of the poles, merely upon the change of the situation, it also appeared that the iron owed its virtue only to the magnetism of the earth; not that of another load-stone which wou'd not have been thus easily alterable."

I need not call your attention to the marked similarity between the manner in which Boyle conceives magnetic induction to take place, and our modern notions concerning the same phenomenon. His streams of magnetic effluvia correspond exactly in direction and action to our present conceptions of magnetic flux and lines of magnetic force.

Coming now to the time of Faraday, we find in a paper, published by Faraday in the *Philosophical Transactions*, in 1852, the following: "From my earliest experiments on the relation of electricity and magnetism, I have had to think and speak of lines of magnetic force as representations of the magnetic power, not merely in the points of quality and direction, but also in quantity." * * *

"A line of magnetic force may be defined as that line which is described by a very small magnetic needle, when when it is so moved in either direction correspondent to its length, that the needle is constantly a tangent to the line of motion." * * *

"These lines have not merely a determinate direction recognizable as above, but because they are related to a polar or antithetical power, have opposite quantities or conditions in opposite directions. These qualities, which have to be distinguished and identified, are made manifest to us, either by the position of the ends of the magnetic needle, or by the direction of the current induced in the moving wire."

As to the direction of the lines of magnetic force, Faraday, as is well known, regarded them as coming out of one pole of the magnet and passing in at the other pole, and referred to this in a paper printed in the *Proceedings of the Royal Institution*, on the 23d of January, 1852, as follows:

"The lines of force already described will, if observed by iron filings or a magnetic needle or otherwise, be found to start off from one end of a bar-magnet, and after describing curves of different magnitudes through the surrounding space, to return to and set on the other end of the magnet."

There is, of course, a danger in quoting from an early writer, of reading into the quotation a significance that it could not have had, save by the light of subsequent researches. It is far from my purpose, or desire, to belittle the researches of Faraday. I merely desire to show by a comparison of the writings of these two philosophers, the remarkable advance that Boyle had made as to the manner in which a magnet acts.

In the above quotation from Boyle it must be remembered that Boyle referred to certain effluvia which he believed were given off by the magnet. His conception, however, of these particles coming out at one pole and reëntering the other, and his mentally endowing streams of such particles with polarity, or the possession of opposite properties in opposite directions, was certainly a remarkable advance for his times and shows how far he was beyond his contemporaries.

It is possible that other writers before the time of Boyle, or between his time and that of Faraday, may have expressed somewhat similar ideas. I merely call your attention to the quotations from Boyle as showing the remarkable grasp of magnetic phenomena possessed by this early philosopher.

NOTES ON ELECTRO-MAGNETIC MACHINERY.

[SECOND PAPER.]

By Wm. S. Aldrich, M.E.,
Associate in Mechanical Engineering, Johns Hopkins University.

[*Read at the meeting of the Electrical Section held January 5, 1892.*]

Electro-magnetic Reciprocating Mechanisms form a class rapidly developing in application to work requiring controlled reciprocation with definite variations of the energy of the stroke. These two questions—the kinematics and the dynamics of this mechanism—have been met in what may be styled the *multiple-coil solenoid.* It will be of interest to lead up to the form developed in the Van Depoele machine—from the electro-magnetic point of view. The several steps do not always (in some cases very rarely) coincide with the evolution of the idea from its earliest inception in the mind of the inventor. But, examining how a given electro-magnetic mechanism could have been evolved—finding how it came to be as it is—may be of service in the development of new forms—quite different in principle and application, yet worked out in more or less accord with the laws of kinematic synthesis; that is, the development of a machine for definite work and certain required motions.

Multiple-coil Solenoid Mechanisms require to be energized by currents of variable potential, producing variable and shifting magnetic fields of force, which may be caused to act in conjunction with or in opposition to each other. These potential variations in the respective coils may be produced and controlled by adjustable external resistances, or by one or more rotating brushes around the commutator of a dynamo.* In either case, variable undulating (pulsating), or alternating currents, may be produced from a source of constant potential. The loss of energy in adjustable resistance being very objectionable, the rotating-brush mechanism is used—fulfilling the fundamental purpose. This is to convert the electrical energy of a continuous-current machine, rotating at its most efficient speed, into undulating currents having any desired rapidity of succession, corresponding to the number of reciprocations of the plunger core working as a piston within the solenoid. The kinematic question is therefore met by fulfilling the conditions of comparative motion in mechanism—(Willis) the directional relation between the rotating brush and the reciprocating plunger, and their velocity ratio of movement. And it satisfies another condition, stated by Reuleaux, in that the relative motion between the two elements is under constrainment, even if this is brought about by electro-magnetic stresses in the ether medium, rather than by the molecular stresses of rigid connecting links of a kinematic chain. The mechanics of this mechanism—the statics and dynamics of its own peculiar medium for the transmission of energy, show that the electro-magnetic forces of Nature can be compelled to do work. And the ether medium, with its induced electro-magnetic stresses, being as much a *resistant* body as more material mediums with their molecular resistance to change of form or of volume, constitute this combination an electro-magnetic machine, from an adaptation of the definition of Reuleaux, given in the former paper. The tubes of force of the magnetic field may change their *form* to a very great degree, but they remain unaltered in *volume ;* and, it is the resistance of the tubes of force to any change of volume, which answers as well for the performance of work or the transmission of energy or motion, as the resistance of a bar of rigid material to any alteration of its length or general form.* Also, examined in the light of Sylvanus P. Thompson's treatment of electro-magnetic mechanisms,† the one under consideration possesses the characteristic feature that it is a combination in which power is transmitted electrically along a wire, and made to produce, through its electro-magnetic combinations, certain mechanical motions.

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* As in the Van Depoele Pulsating Electric Generator, United States Patent, No. 422,855, March 4, 1890.

The Single-coil Pulsating-current Solenoid is shown in *Fig. 1*, diagrammatically, in combination with the rotating brush *M*

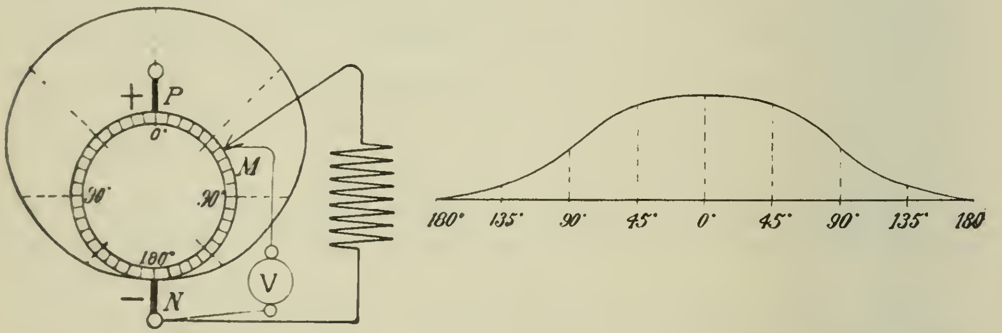

FIG. 1.　　FIG. 2.

Single-coil pulsating-current solenoid mechanism, with ideal integrated curve of potentials.

and one terminal of the stationary brushes *N*, of the dynamo. What Sylvanus P. Thompson has called the integrated curve of potentials, being the total or integrated potential taken at each bar all round the commutator (by the indicated voltmeter connection) has been plotted in its simple *ideal* form, around the commutator in *Fig. 1*, and as referred to rectangular coördinates in *Fig. 2*.

It is the line-integral of the ideal (sine) curve of induction ; and, any ordinate represents the total induction from the fixed brush *N* up to that point of the rotating brush *M*. With the rotation of the brush *M*, there is produced a variation of potential through the solenoid coil, a corresponding undulation of current strength and so a variation of ampère turns and a rise and fall of the intensity of magnetization of the solenoid core. This causes the plunger to be drawn into its coil with variable energy, according to the laws of the magnetic circuit, by which it continually so tends to place itself that it shall be in the field of maximum induction at any one time. The action is only in one direction—after reaching the maximum, at 180°, the plunger gradually falls out of the coil by its own weight, or is retracted by a spring to its original position. If the rotating brush is held at any position around the commutator, the plunger will remain in its corresponding position for that point; being in more or less stable equilibrium between the electro-magnetic stresses of the ether medium, and the force of gravity or of a retracting spring. It would be possible to give a slight oscillation to the plunger in this position, as it is under the action of the contractile energy of the tubes of force, which is a property that the current has conferred on the ether medium surrounding the coils; by this its tubes of force develop a marked tendency to shorten in the direction of their length, and spread out in directions at right angles to their length. The integrated curve of potentials represents an entirely ideal condition of the cycle of operations; and does not indicate that the intensity of magnetization will proportionally vary in more than a quite

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* Compare Rankine, *Machinery and Millwork*, chap. iv, sec. viii, art. 207. Thurston, Introduction to *Kinematics of Machinery*, Van Nostrand's Science Series, No. 54, p. xi. Kennedy, *Mechanics of Machinery*, chap. i, sec. 1.

† *The Electrical World*, 1891, January 17th ; also, in his work on *The Electro-magnet.*

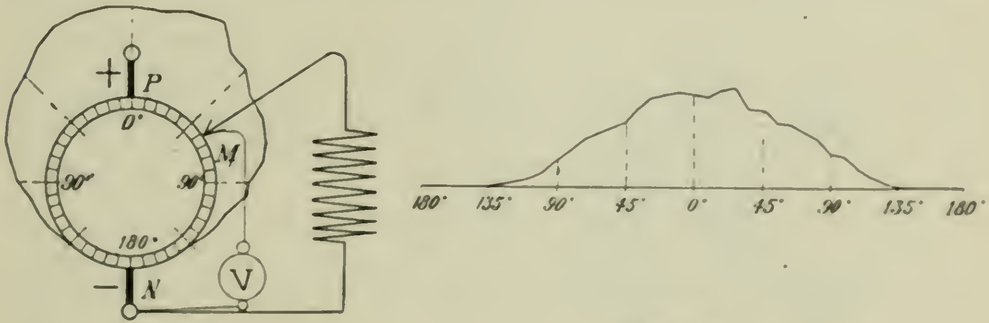

FIG. 3. FIG. 4.

The single-coil electro-magnetic mechanism, with real integrated curve of potentials.

general way. The several resistances in the path of the magnetic circuit—that of the air gap and of the iron portion—as well as the counter-electromotive force dependent on the speed of reciprocation, and the movement of the plunger into and out of the field of force, will continually vary the resultant effect of the variable field of force. It becomes then, rather difficult to plot exactly the real flow of magnetic stress along the corresponding positions of the plunger. It belongs to the class of intermittent mechanisms; and, like single-stroke devices, requires reactive forces to restore it to its original position. From the point of view of electro-magnetic kinematics, it is a simple one-circuit (magnetic) mechanism, of constant direction (polarity) and variable intensity (of magnetization or of induction).

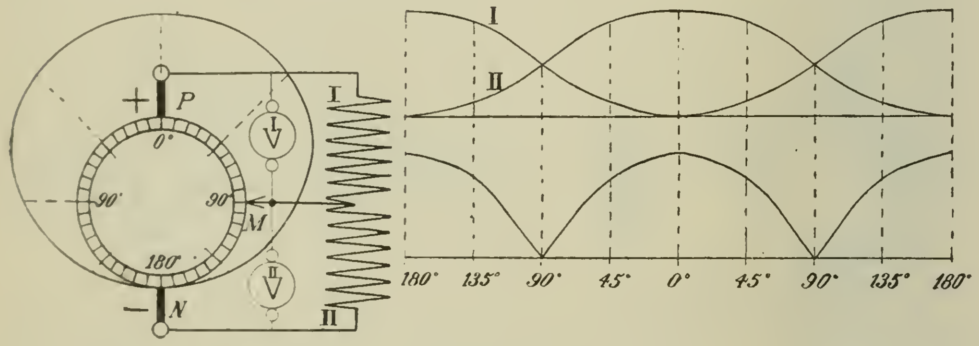

FIG. 5. FIG. 6.

Two-coil pulsating-current solenoid mechanism.

Figs. 3 and *4* show the *real* curves of the distribution of potential, taken with voltmeter, as indicated, and with no other external circuit, from a small separately-excited motor, run as a dynamo, with constant field.

The Two-coil Pulsating-current Solenoid has its outer terminals connected to the fixed brushes, *P* and *N*, as in *Fig. 5*, and the inner join of the same coils to the rotating brush *M*. The resultant action of the two fields of force of the coils, may be quite different: (*a*) according to whether the two coils are connected up to operate in conjunction with each other, as two parts of one coil, called a differential coil-and-plunger mechanism, by Sylvanus P. Thompson; or (*b*), when the two coils are connected up in opposition to each other, producing variable electro-magnetic stresses working against each other. In the former case the mutual actions of the two solenoid coils are reciprocal, the energizing effect of one of the coils increasing from zero to a maximum, while the other decreases from a maximum to zero, as the rotating brush is moved around the commutator a half turn, indicated in a general way by the ideal curves of integrated potential, the upper curves of *Fig. 6.* This ideal cycle of operations being completed shows two nodal points—positions of electro-magnetic equilibrium—when the plunger is under the action of balanced electro-magnetic stresses. This equilibrium is more or less stable, depending upon whether the two coils work with or against each other. The lower curves, *Fig. 6*, represent what may be termed the effective electro-motive force, being found by taking the differences of corresponding ordinates of the upper curves. The portions between the nodal points are really of opposite sign, representing a reversal of the resultant effect of the variable magnetic fields. The plunger, on passing the nodal point, as a position of zero pull, goes more completely into the range of action of the increasing magnetic field and out of the decreasing field of the other coil. The combination of the two coils acting in conjunction, results in an almost constant magnetization of the plunger, so that it has generally a steady pull and a regular movement, in which it follows the movement of the field of maximum induction of the solenoid coils, determined by the rotating brush *M.* It is a double-acting mechanism, giving two controlled reciprocations of the plunger for one rotation of the brush *M.* For producing hammer blows, regulating switches may be used to vary the intensity of the magnetic field, according to the location and character of the work. The electro-magnetic conversion of continuous circular into reciprocating rectilinear motion may be accomplished with equal facility and regularity, for almost any intervening distance, an advantage not possessed by its somewhat analogous mechanical (kinematical) equivalents of finite connecting rod, nor of the so-called infinite connecting rod.

Multiple-coil Pulsating-current Solenoids admit of varying the power stroke, as in hammer-blows, to meet requirements of the work, while there is a very light return stroke to prevent excessive wear and tear of the machine. By winding the solenoid coils in three or more sections, of equal resistances, longitudinally disposed, and connecting the two or more forward sections in parallel with the supply wires and the back section singly—the current through this section will be correspondingly less than that through the other section with joint resistance in parallel.* This arrangement will therefore throw the preponderance of power in the forward stroke.

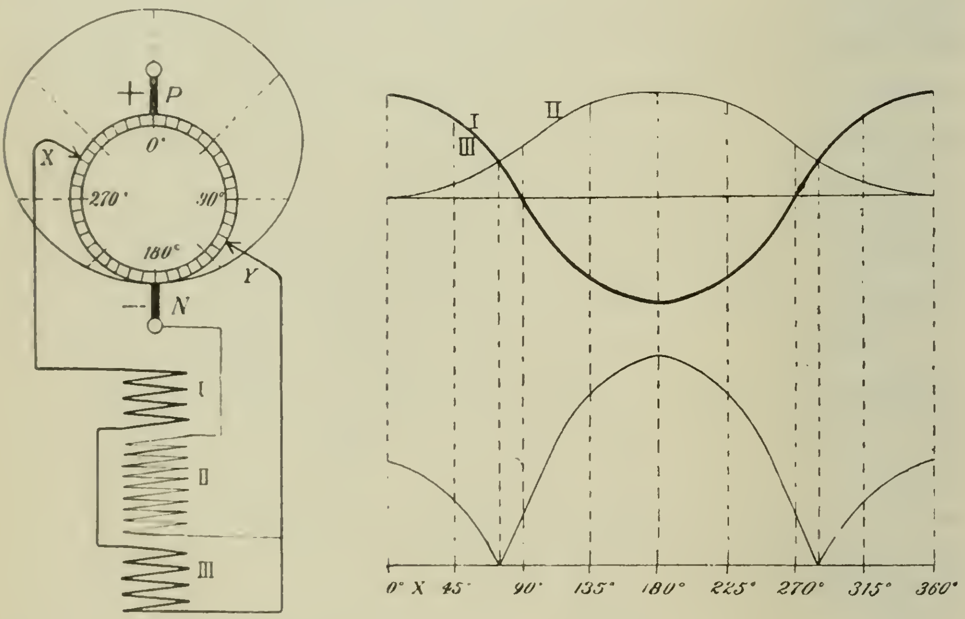

FIG. 7. FIG. 8.

Three-coil pulsating- and alternating-current solenoid.

The Three-coil Pulsating- and alternating-current Solenoid, with two rotating brushes, is shown in *Fig. 7.* Another but similar diagram,† was explained at the close of the former paper. At the same time that there is a controlled reciprocation, the combination of the pulsating current through the fine-wire coil *II*, with the alternating current through the coarse-wire coils *I* and *III* gives a heavy power stroke in the forward direction and a light return stroke. *Fig. 8* shows this in the form of the potential cycle, the light-line curve *II* being the ideal curve of the integrated potential for the pulsating current of coil *II*, and the heavy-line curve *I—III*, that for the alternating-current coils *I—III*. The lower curve represents, as in *Fig. 6*, the differences of the corresponding ordinates of the upper curve. There are several pecularities of these curves; and, though entirely ideal, may serve to aid us in forming some notion of the real distribution of electrical energy in the solenoid coils. The nodal points are both on the return-stroke end of the plunger-cylinder, encasing the mechanism. The long ordinate at the centre shows a very heavy power-stroke forward, while the short ordinates at the ends show light return strokes, with more or less of a cushioning effect. The action of the energizing polarizing coil *II*, shows how its pulsating current—in the one case causes a very rapid increase of the resulting maximum induction, and in the other, at the end of the stroke, having no effect, as it simply rises and falls between zero and a maximum. The alternating current passes from maximum to maximum in opposite directions, and cuts the pulsating curve nearer the weak end of each case. The iron core, under the chief energizing coil *II* is not electro-magnetically equivalent to a permanent magnet core, for it is now *variably* energized in one direction, at about the proper points. But, in the latter case, its constant magnetic field would seriously interfere with this very arrangement of the two kinds of currents to produce maximum forward stroke. By reversing the connections of coil *II*, the other stroke will be a maximum. More than three coils may be used, and the respective positions of the pulsating and of the alternating-current coils may be reversed, or otherwise arranged to suit the requirements of the work.

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* Van Depoele's method, set forth in United States Patent, No. 422,855, March 4, 1890.

† From *The Electrician* (London). Vol. xxviii, Nov. 6, 1891, p. 10.

Derived Mechanisms from Multiple-coil Solenoids admit of many industrial applications. For instance, it gives at once a kind of electro-magnetic *dash-pot*, buffer, cushion, brake or clutch for reciprocating movements. And this possesses capabilities of adjustment not usually found in rigid or even flectional-element mechanisms, of changing quickly and surely the intensity of the tractive force as well as the position of its static equilibrium. Periodically varying the speed of rotation of the brush *M* will result in corresponding variations in the rate of reciprocation, with or without changing length of stroke. The length of stroke may be changed by auxiliary and solenoid coils. On the other hand, the speed relations may be maintained constant, and the power stroke varied at will, or both may be varied to any desirable extent. Another modification, which would produce multiple nodal points, would give multiple-reciprocation mechanism (*reduplication*, of Willis), obtaining four, eight, or more reciprocations for one rotation. For the stress nodal points indicate the electro-magnetic dead centres, of which there must be as many as the number of reciprocations desired. So with electro-magnetic *cams*—the stroke of the plunger may be made to follow any given law of cam curves or spirals, as the Archimedian or logarithmic, by simply controlling the rotating brush *M*, according to the same law. And the stop, dead and change points of ordinary cam plates may be controlled with equal facility by this electro-magnetic combination. Electro-magnetic *ratchet* mechanisms, where there is no special return or reversal of motion, may be equally developed from the solenoid mechanism, chiefly of the multiple-coil types, with the coils connected up in series, as in the port-electric and other electro-magnetic package-carrying devices.

The Cycle of Operations of Electro-magnetic Machinery possesses features characteristic of the ether medium employed. The fundamental cycle is necessarily that of the physical condition of the medium at each point; following this are the energy cycles of the medium and throughout the mechanism, and the kinematic cycle of the mechanism of transmission. Or, perhaps more generally, the transformation or conversion cycles of the medium would be considered first, then the transmission cycles of the intermediate mechanism and machinery, through which the transformation cycles indicate the performance of useful work by the so-called mechanical forces of nature. Each of these elements of the complete cycle—the ether medium and the mechanism of transmission—may again be considered, especially with reference to the *mechanics* of the elements involved; that is, the mechanics of the electro-magnetic stresses of the ether medium as of a *resistant* body,* and the mechanics of the molecular stresses of the material elements of the electro-magnetic machinery. In considering in a somewhat analogous way, the mechanics of the medium and the mechanism of the steam engine, Prof. R. H. Thurston† has extended the point of view along the lines of Rankine, and thus groups under the heading of *Mechanics:*

(1) *Statics*, treating of the relations of forces in any system or medium, when no motion results from their action.

(2) *Kinematics*, treating of the relations of motion simply.

(3) *Dynamics*, or kinetics, treating of the action of forces accompanied by motion.

(4) *Energetics*, treating of the transfer, transformation, transmission or modification of energy, under the action of forces, from one mode of manifestation to another, and from one body to another.

Examining, for a moment, the application of the above to electro-magnetism, with ether as the medium, it will be found that the lines have already been mathematically laid out by Maxwell in the direction of electro-statics, electro-kinematics and electro-dynamics, resting somewhat anteriorly upon Faraday's researches and posteriorly upon Hertz's experiments. We have noted the statical action of the electro-magnetic stresses, when under more or less stability of equilibrium, as in the solenoid mechanisms; the kinematic conception of the ether mechanism, as stated in the former paper, has served fairly as a working hypothesis, in lieu of a better; while the dynamical conception has shown the ether to be a suitable medium for the transfer or transmission of energy accompanied by definite motions. In order to investigate the complete cycle of operations of an electro-magnetic mechanism, the whole of its mechanics should be developed—for the ether medium and for the machine elements. This, therefore, involves the *energetics* of the medium, giving the etheric energy cycle (electro-dynamic), as we have for the steam engine the thermo-dynamic cycle. And, the energetics of the ether medium may come to be studied by autographic records of its energy cycle, bearing the same relation to the electro-magnetic mechanism that the indicator card does to the distribution of energy in the steam-engine mechanism.

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* *Resistant* in the sense of acting as a body constantly maintaining its volume while undergoing any kind of alteration of its volume-form.

† *Manual of the Steam-engine*, Part I, pp. 298 and 304.

Differential Electro-magnetic Mechanisms may consist: (1) of variable-speed or power (or both) combinations effecting their purpose by electro-magnetic action, not necessarily of itself differential; (2) of variable-action mechanisms having a differential effect brought about in the electro-magnetic stresses themselves. In the former case, the mechanism is inherently differential, whether controlled, operated or actuated electro-magnetically or pneumatically for instance; such would be a differential screw, pulley or other *mechanically* differential mechanism. In the second case, we have the two-coil solenoid; the solenoidal electro-magnetic balance, and the dynamotor balance shown later, the differential action being due to a preponderance of a simple or of a resultant magnetic field over a surrounding field or fields.

Epicyclic Gear-wheel Mechanisms are differential in character, as may be seen by referring to *Fig. 9*. The motor armature M_1 and gear-wheel A are secured to a sleeve, loosely turning on shaft $P P$, and the motor armature M_2 and wheel B, similarly placed on shaft $S S$. Three principal combinations of these three elements of a simple kinematic chain are possible. (1) If the arms $X X$, connecting the shafts, are fixed—one machine will drive the other as a dynamo—the fields being supposed secured to the arms $X X$. (2) if shaft $P P$ is held in fixed bearings, field of M_1 stationary, and both motors set in operation, the arms $X X$ will carry combination around the shaft $P P$, when the motors revolve at different speeds. The arms $X X$ will turn around in a direction dependent upon the direction of rotation of the motors, and at a speed proportional to the speed of the motors and the number of teeth on the wheels. When the wheels have the same number of teeth: (*a*) and the motors revolve at the same speed in the opposite direction, there will be no rotation of the arms; (*b*) motors revolve at different speeds, the arms will turn at a speed of half the difference of the motor speeds, and in the direction of the greater one. (3) If shaft *S S* is fixed, instead of *P P*, field of M_2 stationary, similar combinations will produce similar results in effecting the rotation of the arms. Several minor combinations are possible in each case, but the above serve to show the differential nature of this form of a simple epicyclic gear-wheel train.

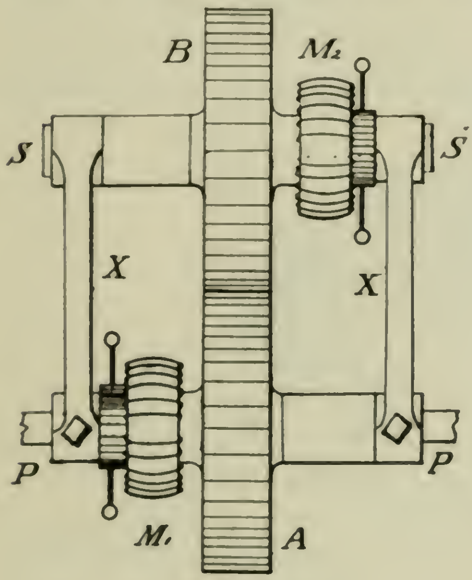

FIG. 9.

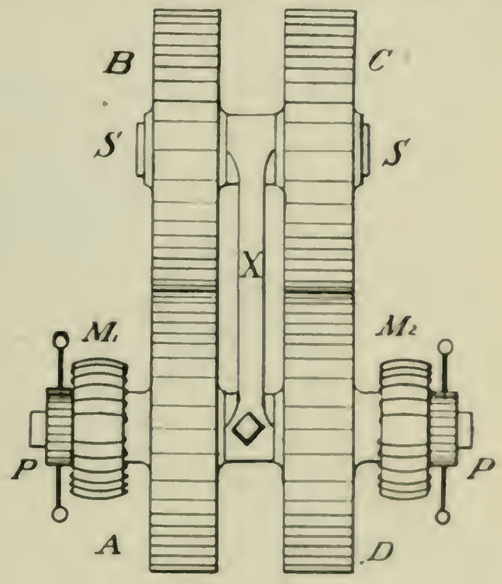

FIG. 10.

Epicyclic spur-wheel mechanisms, driven by electric motors.

In *Fig. 10* motion is communicated to the wheel *B* through the wheel *C* on same sleeve as *B*, and geared to *D* on same sleeve as motor armature M_2, loosely mounted now, on shaft *P P*. This is permanently mounted in bearings, and has no rotation, when the gear wheels *A D* and *B C* are of same size, and the motors M_1 and M_2 revolve at same speed in same direction. When the motors M_1 and M_2 revolve in the same direction at different speeds, the arm *X* (keyed to shaft *P P*) rotates at a speed equal to half the difference of the motor speeds.

In *Fig. 11* bevel wheels have been substituted for the spur wheels of *Fig. 10*, reducing the number; as the bevel wheel *B*, loosely sleeved on the arm *X* meshes with *A* and *D*, and so performs the mechanical functions of both the wheels *B* and *C*, of *Fig. 10*. The motors M_1 and M_2 are mounted as before, and cause no rotation to the arm *X* or shaft *P P* when they revolve in opposite directions at the same speed. When so revolving, at different speeds, they rotate the arm *X* at a speed of half their difference of speeds, in the direction of the greater. This is the fundamental form of the Edison epicyclic street-car gear. A slight alteration in the speed of the motors above or below their normal speed, or one above and the other below the normal, will rotate the car-axle *P P*, and drive the car forward or backward, according to the direction of rotation of the motor having the greater speed. Sometimes the arm *X* and wheels *B C*, *Fig. 10*, are duplicated on the other side of the shaft, as in *Fig. 16*, which distributes the strains, but in no way changes the kinematical relations. A similar addition to *Fig. 11* is to extend the arm *X* and loosely mount fourth bevel wheel on it, between *A* and *D*. All of these are simply electrically-driven epicyclic gears.

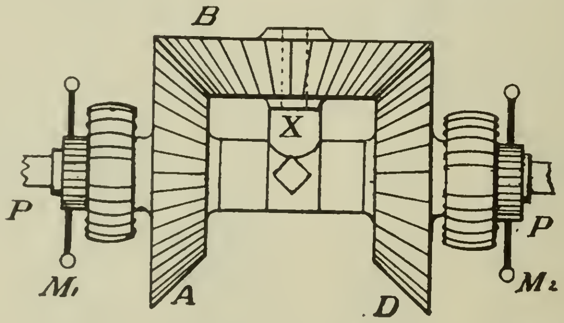

FIG. 11.—Epicyclic bevel-wheel train of mechanism.

Epicyclic Electro-magnetic Mechanisms may now be derived by substituting dynamotors (or double motors if needed) for the pair or pairs of gear-wheels. In *Fig. 12*, the dynamotor combination *C D* has been substituted for the two wheels *C D*, of *Fig. 10*, discarding motor M_2. For armature *D* being mounted on the same sleeve with *A* and *M*, and so driven by *M*, now operates as a dynamo, supplying current to armature *C*. This is on same sleeve as wheel *B*. The dynamotor fields are secured to arm *X*. Therefore, while the motor *M* is run at a constant speed all the time, the dynamotor *C D* being then operated as a variable-speed dynamotor, the speed of *C* may be varied at will. As the fixed speed-relation between the gear-wheels *A* and *B* cannot change—an increase or decrease of the speed of *C* from the normal, will cause the arms *X X* to rotate the shaft *P P*, in the same way that *Figs. 9* and *10* would operate if the motor M_1 were run at constant speed while motor M_2 should

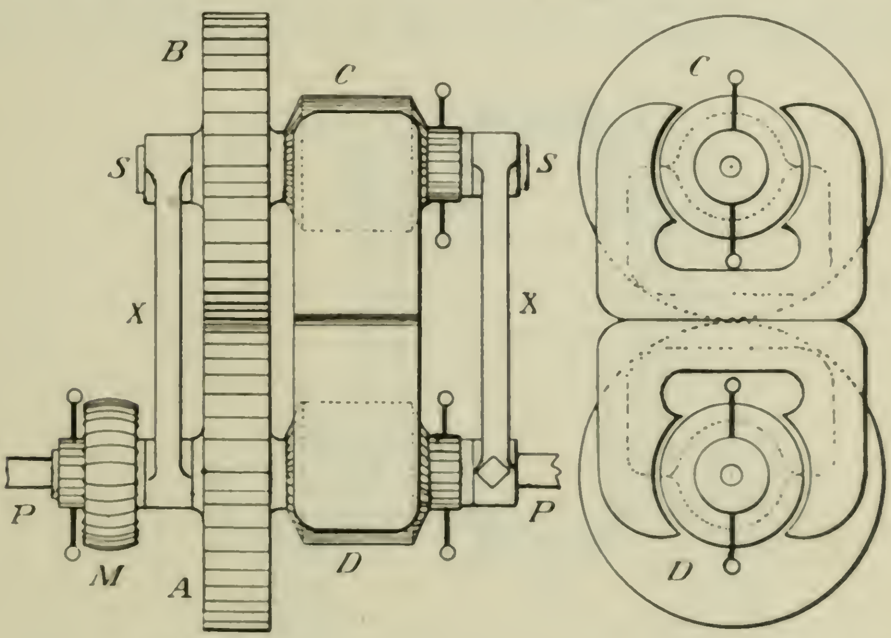

FIG. 12. FIG. 13.

Combination of spur-wheels and dynamotor in an epicyclic train.

be varied as we have now supposed motor *C* to have been. *Fig. 12* might also have been derived from *Fig. 9* by putting in the dynamotor *C D* instead of the motor M_2. *Fig. 13* is a side view of the dynamotor of *Fig. 12*. This is yet a combination of mechanical and electro-magnetic elements. Drop the wheels *A* and *B*, giving form in *Fig. 14*.

Fig. 14 is the true electro-magnetic and epicyclic mechanism combined. The dynamotor fields are secured to the arms *X X*. The motor *M* driving it, tends to drive the armature *A* as a dynamo, but both *A* and *B* are connected up with the external circuit, either as a constant or a variable-speed dynamotor. Therefore, if motor *M* runs free (open circuit) there is no rotation to the arms *XX*, while *A* and *B* are revolving all the time at a nominally fixed speed-relation.

(*a*) Now, upon operating *M*, as a motor, but against the rotation of *A* (and therefore, as a brake to *A*), the armature *A* will be slowed down, which will cause the field of the dynamotor and arms *X X* to rotate in the opposite direction of armature *A*, in order to continue cutting the lines of force across armature *A* at same rate as before, and so to maintain the constancy of the nominal speed-relation between armatures *A* and *B*. Should the armature *A* be slowed down till it stops, the dynamotor field will increase its speed of rotation till up to the former speed of its armature *A*, and will maintain that speed, still in the opposite direction, as long as armature *A* is held stationary, by the armature of *M*, on its sleeve, being now electro-magnetically clutched by its stationary field. Slowly releasing armature *A*, will cause it to react against its dynamotor field, tending to stop it; when armature *A* is once more free the arms *X X* are stationary again.

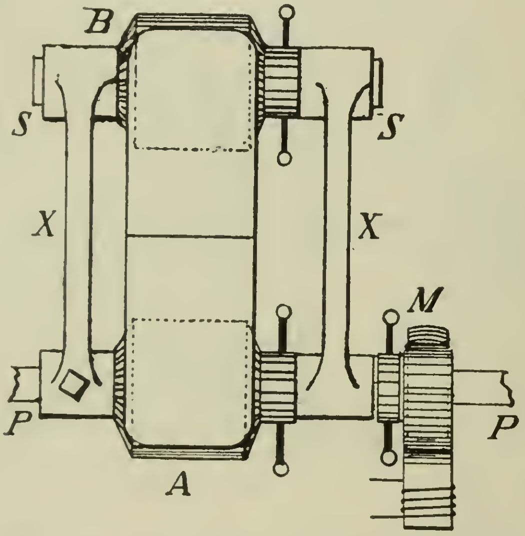

FIG. 14.—Epicyclic electro-magnetic mechanism.

(*b*) By again operating *M* as a motor, but causing its armature to rotate in the same direction that it had been going when free, and increasing its energy gradually, it will cause the armature *A* so to react upon its dynamotor field, as to continue to cut across the lines of force at same rate as before, which will therefore give a rotation of the dynamotor in the *same* direction as its armature *D*.

Besides controlling the motion of the dynamotor field (and so of its arms *X X*, and shaft *P P*), entirely by motor *M*, it may be partly controlled by regulating the external circuit supply to the dynamotor fields and armatures.

Fig. 15 is a double form of this mechanism, derivable from *Fig. 14*, by adding another dynamotor, or from *Fig. 12*, by substituting a dynamotor *A B*, for the gear-wheels *AB*. One or both of the dynamotors may be variable-speed combinations; and one only or both may therefore be under control of the external circuit. The armatures *A*, *D* and *M* are all on same sleeve, loosely mounted on shaft *P P*. The armatures *C* and *D* are on same sleeve, loosely mounted on shaft *S S*. The operation is analogous to that of *Fig. 14*.

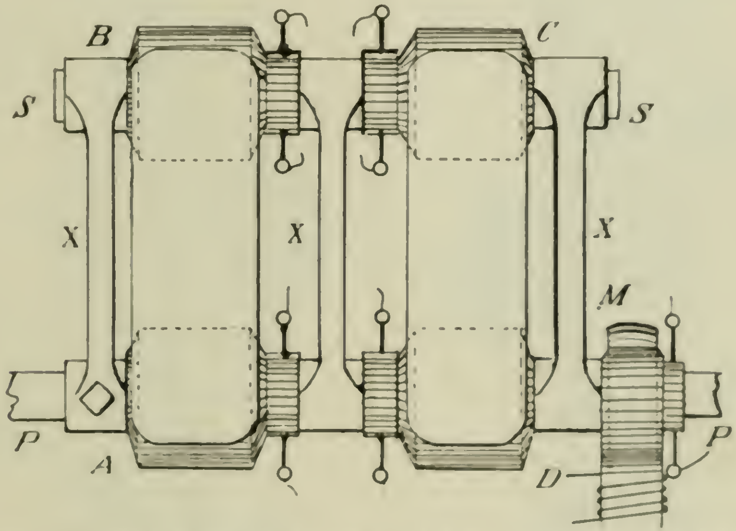

FIG. 15.—Double form of epicyclic electro-magnetic mechanism.

Fig. 16 is a double form of the gear wheel form of *Fig. 10*, and *Fig. 17* is a double form of the combination shown in *Fig. 12*.

Three-armature Dynamotors are shown in *Figs. 18* and *19*, the former having a two-branch magnetic circuit, and the latter a four-branch circuit. Either of these will serve for the combination shown in *Fig. 17*. All of the armatures of either *Figs. 18* or *19* may be run: (*a*) as dynamos with electrical output of current; (*b*) as motors, with mechanical output of power; or, (*c*) one or more may be run as dynamos supplying current for the remaining armatures, as motors, in the same magnetic fields. The differential operation of the branch circuits *C* and *D* would result in no flux of lines across armature *Q*, when the fields of *C* and *D* were exactly balanced. We have then electro-magnetic equilibrium, as formerly in the solenoid mechanism, and more or less stable, according to the character of the balanced fields of force. Moreover, there is constant air-gap resistance here, independent of the position of the balanced circuits, as was not the case with the differential coil-and-plunger mechanism. This eliminates the many disadvantages of the electro-magnetic

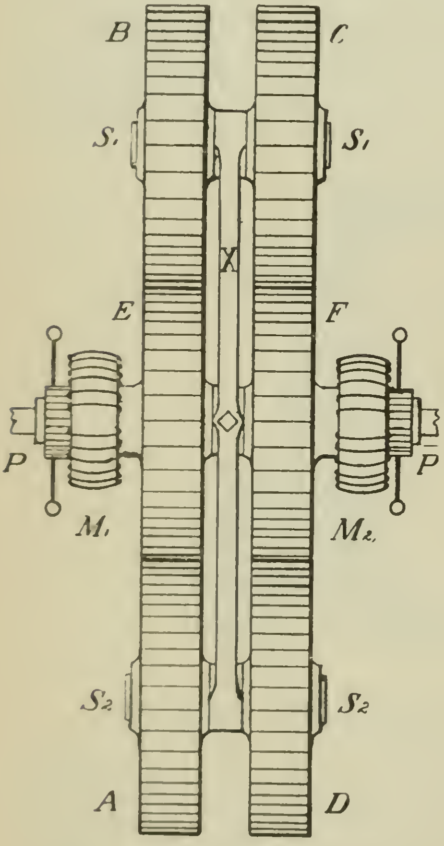

Fig. 16.

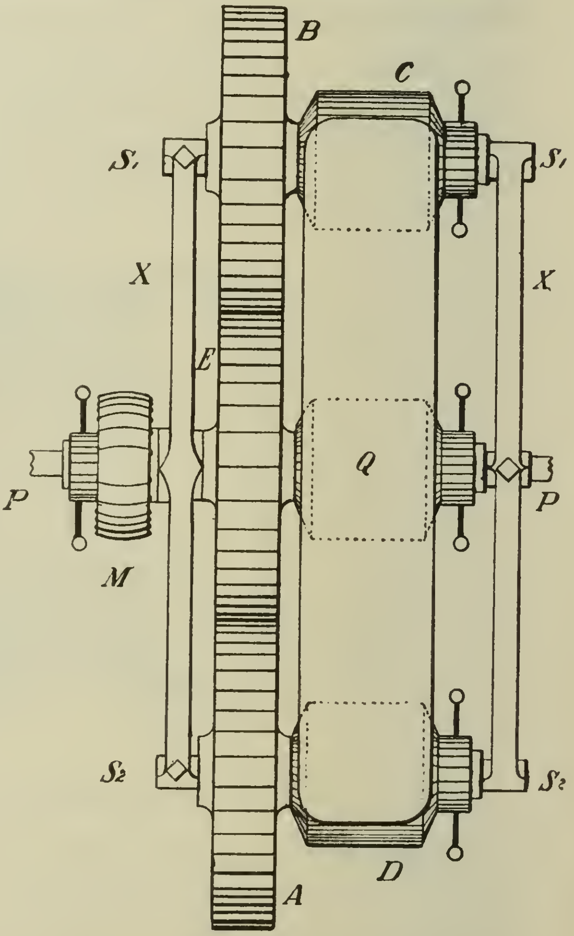

Fig. 17.

Double forms of epicyclic mechanisms, derived respectively from *Figs. 10* and *12*.

balance in the solenoidal form, and may give this type, or a modification, some useful purpose to fulfil as a measuring instrument. When there is an exact balancing of the magnetic flux from *C* to *D*, on each side, there will, of course, be no rotation of the armature *Q*. And when there is not a balance, it will either cause a rotation of the armature *Q* (if the dynamotor field is fixed), or cause an angular swing of the field (if the armature *Q* is held stationary). This swing of the field is somewhat analogous to the swing of the field of a dynamo when mounted in the form of the Brackett cradle dynamometer. Within certain limits the angular deflection is a measure of the torque.* Brackett states that if the counterbalancing effort of the spring balance or weights be removed, the field will perform a complete revolution and

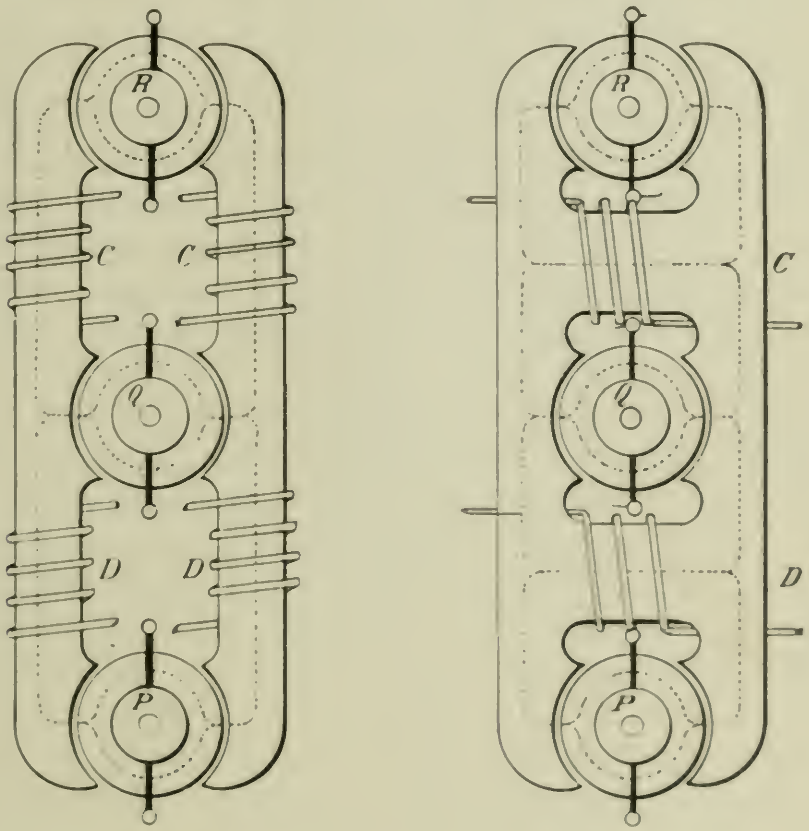

FIG. 18. FIG. 19.

Three-armature dynamotors.

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* Used at the Stevens Institute of Technology, 1884, and described in the *Electrical World*, Jan. 5, 1884.

go on revolving, increasing its speed till it and the armature (practically) revolve together; when, of course, there is no work done but in overcoming internal and external friction. This action of the field and armature is analogous to that considered for the combinations of epicyclic mechanisms, *Figs. 14* and *15*.

The Efficiency of Dynamotor Transmission should approximate to that of the motor-dynamo transformers, the one being practically the reverse operation of the other. Sylvanus P. Thompson has considered* continuous-current transformers to be capable of a high average efficiency. Lahmeyer employed the principle of the dynamotor,† consisting of an armature turning nominally without load, as a variable resistance, to regulate the (constant) number of turns of the working armature. In Lahmeyer's constant-current transformer,‡ of the one-armature type, wound both for high tension supply and low tension demand, all in one magnetic field—we have a form of construction of high practical value. There is higher efficiency at less cost and decreased size, with less sparking than in motor-dynamo transformers. With equal excitation this transformer works with a higher degree of magnetic saturation—because the reactions of the armature coils balance each other, a condition obviating sparking. The efficiency of transformation is about ninety-two per cent. The Bernstein constant-current transformer § has its motor armature wound with thick wire, the dynamo armature with thin wire, entirely separated longitudinally, and turning in a common magnetic field, which is excited by the current in the primary wire. Being a series-field, with primary field in series with the thick-wire coils of the magnet—the speed varies directly as the electro-motive force required, a peculiarity of some importance in certain work. Elihu Thomson's continuous-current transformer,* for a three-wire system, has an armature consisting of a double winding of two separate sets of coils, the counterparts of each other in potential energy, and each set having a brush and commutator of its own. The armature windings of this so-called "compensator" are of quite low resistance and designed to give, at its normal speed, an electro-motive force respectively equal to that existing between the side wires and centre wire of the three-wire system. Isolated plant forms of dynamotor transformers are to be seen in the telephone and hotel service electrical work.† And several typical forms of dynamotors have been exhibited at the Frankfort Exhibition last year, details of which may be seen by referring to the current journal reports and correspondence of that period. Respecting the peculiar conditions likely to arise in using the dynamotor in form of an epicyclic mechanism, the field and armature both revolving, Patten has developed a form‡ of dynamo with *revolving* fields and armature. With careful design, construction and management of operations, the dynamotor should range as high as ninety per cent. efficiency as a maximum.

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* Paper before the International Electrical Congress, on "Constant Current Transformers," Paris, 1889. See *Electrical World*, Sept. 21, 1889.

† *Electrical World*, Oct. 12, 1889.

‡ *Engineering*, London, May 29, 1891, p. 642.

§ *Electrical World*, Jan. 25, 1890.

The Kinematics of Electro-magnetic Machinery has been touched upon in the foregoing sections, chiefly with reference to the propriety of including electro-magnetically connected mechanisms with previous typical forms, the mechanical equivalents of dynamotors, and the conception of the electro-magnetic kinematic chain. It remains to be seen whether this portion of the subject may be further developed along existing lines of treatment and classification, as outlined by Willis, Rankine and Reuleaux; or, whether it may not be found to require a peculiarly distinct treatment, owing to the special need of considering the character of the medium, and its own kinematics and dynamics. But, in the present state of our knowledge it is well to guard against too rigidly adhering to only the kinematical and mechanical conceptions of the ether medium. It is not that the true conception is necessarily otherwise; but, because the electro-magnetic mechanism appears to have many well-known mechanical equivalents. For, almost all the kinematical problems may be solved by electro-magnetic connection, in some cases more readily than by mechanical devices.

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* *Electrical World*, April 16, 1887.

† *Electrical Engineer*, New York, Dec. 23, 1891.

‡ *Electrical World*, Nov. 26, 1887.

The Characteristic Features of the Ether Medium led Maxwell to identify the two phenomena of light and electro-magnetic waves, basing upon this identity his electro-magnetic theory of light. Prof. Henry A. Rowland remarks* that "as yet we cannot conceive of the details of the mechanism which is concerned in the propagation of an electric current. . . . According to our modern theories of physics there must be some medium engaged in the transmission. . . . That medium which is supposed to extend unaltered throughout the whole of space, whose existence is certain, but whose properties we have yet but vaguely conceived; . . . we have finally completely identified the ether which transmits light with the medium which transmits electrical and magnetic disturbances." And, regarding the possibilities bound up in the intensity of the electro-magnetic stresses which are capable of being induced in the ether medium, Mr. A. E. Kennelly states† that they are far in excess of any stress which we can exert without the cohesion of matter. He estimates that one cubic inch of electro-magnetically stressed air, magnetized to a flux density of 5,019 lines per cubic centimetre, and alternated 227 times per second, would store and release energy at an average rate of one horse-power. So that for range of adaptability in meeting the requirements of comparative and constrained motion, as well as for great concentration of energy in the transmission and transformation of energy—the ether medium stands out alone, yet with a rapidly increasing field of application.

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* "On Modern Views with Respect to Electric Currents." *Transactions American Institute of Electrical Engineers.* Vol. vi. No. 7, July, 1889.

† *Transactions American Institute of Electrical Engineers.* Vol. viii. No. 11, Nov., 1891.

BOOK NOTICES.

Systematic Mineralogy, based on a Natural Classification, with a general introduction. By Thomas Sterry Hunt, M.A., LL.D. Author of "Chemical and Geological Essays," "Mineral Physiology and Physiography," "A New Basis for Chemistry," etc. The Scientific Publishing Company, 27 Park Place. New York: 1891.

In order to appreciate what Dr. Hunt has attempted, and what he has accomplished, in this book, we must take a short retrospect of the science at the risk of wearying the learned by repeating what all should know. His own excellent preface states the facts in detail, but they may be summarized as follows:

When the science of mineralogy was created by Werner in the first decade of this century, the science of chemistry was so young that neither its methods nor the instruments of which it could dispose were capable of answering the many questions propounded by the sister science. But there was a whole world of undetermined facts in the physiological and physical properties of those curious entities called minerals, and Werner's quick perception set about establishing them and coördinating them for use in a system.

It is as much an error to suppose that Werner and his followers, Mohs and Breithaupt, Jameson and Shepard, undervalued the aid of chemistry, or believed that the "stuff" was less important than the form and attributes, but they simply could not wait till chemistry grew up, and did as well as they could without her aid. The school-boy need not be told that Werner was one of the great founders of the Freiberg School of Mines, and that his chair has been filled first by Breithaupt, and secondly by its present occupant. Albin Weisbach. The school called by Dr. Hunt the "Natural History" school, or that which depends upon extrinsic characters for bases of classification, is therefore very naturally the Freiberg School of Mineralogy, and nowhere else has the fine scrutiny of these characters been carried to so high a point of perfection. It is this school which has created determinative in contradistinction to analytical mineralogy.

But immediately upon its creation a set of opponents arose who said · "Of what use are your properties of minerals if you do not know the constituent elements of which they are composed?" To which the Wernerite replied: "Of what use is the knowledge of the constituent elements of a mineral, if you do not know what its properties and uses are?" Both were right and both were wrong. It was only a recurrence in this science of the same problems which had perplexed others. Even to-day the paleontologist asks the stratigrapher of what use is a determination of the sequence of rocks if one is ignorant of their ages? and the stratigrapher retorts "How can you know their ages if you are ignorant of which were first deposited?" Of the two contending schools, that of Berzelius, Rose, Phillips, Rammelsberg and Alger, or the chemical, was the least conciliatory, and at the present day is the dominant one, in spite of the fact that the progress of what is called physics and of chemistry had been great enough to enable any thoughtful mind to perceive that they were mere branches of the same stem, and that no philosophic insight into the laws of the manifestations of matter and force could be complete without the aid of both.

Dr. Hunt saw this clearly many years ago, and outlined the main features of the treatise which we have before us. In completing it he has rendered two distinctive services to the science, which will not be diminished whether or not his system be adopted. The first of them is the plain or irrefutable demonstration that not only is it not expedient, but that it is impossible to consider minerals from less than the two points of view of their ultimate constitution, and their physical characteristics; that in fact, one of them is a function of the other. The second service he has rendered is that of bringing us face to face with the issue of a scientific nomenclature, and compelling us to state whether we are in earnest in accepting the postulates so forcibly insisted upon by Linnæus and Lavoisier, each in his own science, that the names of the various divisions of a classification should not be trivial but should be based upon such inherent qualities of each class as separate it from its fellows of the same grade while including all the individuals of subordinate divisions within it. All naturalists will assent to the justice of the proposition, theoretically, yet in practice it has been neglected in all sciences, and even in chemistry and mineralogy of which Lavoisier and Werner and Breithaupt made it the foundation stone.

The first nine chapters substitute a general introduction to the subject, and treat respectively of (1) The relations of mineralogy. (2) Mineralogical systems. (3) First principles in chemistry. (4) Chemical elements and notation. (5) Specific gravity. (6) Coëfficient of mineral condensation. (7) Theory of solution. (8) Relation of condensation to hardness and insolubility (a very important and original essay). (9) Crystallization.

Chapter X deals with the constitution of mineral species. Chapter XI gives this new classification on four classes, like that of Breithaupt: Metallaceæ, Halidaceæ, Oxydaceæ, and Pyricaustaceæ. Chapter XII lays down the rules for a nomenclature. Chapter XIII recites the list of classes, subclasses, orders, genera and species. Chapters XIV, XV, XVI and XVII are devoted, one to each of the before-named classes. The XVIII and last chapter is a most interesting and valuable treatise on mineral waters. It must be said that while we are glad to have this chapter here or anywhere, it belongs more properly in a treatise on geology, for even if pure water be a mineral yet saline and mineral waters are "rocks" in the geological acceptation of that term.

The volume is well printed and bound, both type and paper are excellent, and but for a few typographical errors such as never would have occurred had the author been always able to subject the proofs to the searching scrutiny that is a second nature to him, the volume would combine every quality which a book-lover would desire. Such errors are the omission of "der" from the title of Rammelsberg's work on the first page of the preface; the omission of the "p" from "gypsiferous" para. 483, p. 369, etc., etc. But the work is a contribution to science, not the mere collocation of the ideas of numerous dead and living scientists. F.

Boston Society of Natural History: Guides for Science Teaching. No. VIII. Insecta. By Alpheus Hyatt and J. M. Arms. Boston, U. S. A.: D. C Heath & Co., Publishers. 1890.

Any book from the pen of Mr. Alpheus Hyatt merits the attention and is now to receive the praise of the world. He modestly ascribes the success of this charming little book to Miss J. M. Arms, on the ground that it could not have been accomplished in the absence of aid by her. To whomsoever belongs the praise, it is a book of the class to make science popular, because intelligible to the young mind. After the title page comes the Synopsis, which is really an expanded table of contents. As the first-named author says in the Introduction, which comes after the Synopsis: Insects form the most favorable and are apt to become the favorite means for the teaching of observation in the schools. There are twofold advantages to this selection. (1) It tends to obliterate the repulsion which many children have for insects and "bugs." (2) The study of insects will instruct the beginner to distinguish between the noxious and the harmless insects, and to prevent the indiscriminate slaughter of insects because they are insects. Besides these reasons, the collection of insects is made easy at the warmer seasons of the year, by their number and variety, and their preservation and arrangement is inexpensive and comparatively clean work.

The book is very well and thoroughly illustrated by drawings and tables, thus putting the first steps in entomology within the reach of all.

It is a very encouraging sign to see these well-written and modern books on scientific subjects taking the place of the antiquated text books, many of which contain much that is erroneous, and more that is obsolete, with little that is systematic and clear. F.

Nu English. A proposed simplified English language for home use and for international commerce and travel. By Elias Molee, Ph. B, Minneapolis, Minn. A pamphlet.

This is one of the numerous attempts to introduce a phonetic language, of which our English has been the incitement to the greater number, though by no means all.

French and German have each come in for their share of the supposed saving grace of phonetics. It was proper that a Chicago audience should be informed that after the trifling preliminaries of an agreement between a number of civilized nations to teach Nu English, in addition to their native tongue, to ministers, lawyers, diplomats, physicians and school teachers, the whole of the nations would learn it out of curiosity, and we would present the edifying spectacle of an uni-lingual world. The contractions and combinations are very similar to the German in such words as "word-book," lexicon; "fish-love," ichthyology; "bind-word," conjunction, etc.

We are, however, somewhat appalled to learn that "the greatest economy that I know of at present, which is practical, would be the abolition of the capital letters. They ought to be abolished immediately. I say this as a writer, and type-setter, and ex-teacher," etc.

In response to a supposed objection why the proposed reform does not start in Philadelphia, New York, etc., he replies: "The West is to-day the King of the United States." He modestly adds: "Great ideas have seldom started in great cities, though they (?) are the best for making them (?) known." "Grammatical rules depend more upon natural ingenuity than upon philological erudition ! ! !"

There are a few pages devoted to the Nu English as a means of oratory, in which "Ladies and Gentlemana:" "My friendees and my friendina do first five rula, namely, that all nouna," etc., etc.

This is enough. Due notice of the adoption of this dialect by distant nations will be given. F.

Elektro-Metallurgie. Die Gewinnung der Metalle unter Vermittlung des elektrischen Stromes. Von Dr. W. Borschers. (Mit 90 Text-Abbildungen.) Braunschweig: Harold Bruhn. 1891.

The extraction of certain metals from their ores, and the separation and refining of others from the crude mixtures in which they find their way into the market, have of late been very successfully undertaken and carried out in practice by electric methods. The interesting developments of the past five years which have created such a pronounced revolution in the metallurgy of aluminum and its alloys, have naturally attracted more popular attention than any others; but the electric methods by which lead, copper, silver, gold, etc., are separated and refined are no less interesting to the investigator, and of much greater industrial importance. As the application of the electric method to metallurgy is as yet in its infancy, it is scarcely to be expected that the methods employed, many of which are tentative and empirical, should be found fully treated of in the books—and it happens, therefore, that while the general subject of electro-metallurgy is attracting a large share of attention on the part of enterprising specialists, and while information bearing on the subject is eagerly sought after, the sources of such information are limited both as to number and yield.

We welcome, therefore, any intelligent and conscientious attempt to add to our available literature in this field, and the present work will prove exceedingly useful to all who seek information as to the present state of this art. The only works at the present time accessible to English-speaking students are that of Gore on *Electro-metallurgy*, which is neither so recent nor so complete as this, and that of Richards which treats exclusively of aluminum; and Dr. Borschers' work being more recent than either of these, contains data not to be found in the others. The advances in this field are so rapid and radical that, just at this time, an author has little encouragement to write a book, since it is almost an assured fact that in five years it will be regarded as ancient history. W.

"*Makers of America.*" Robert Fulton. His life and its results. By Robert H. Thurston. New York. Dodd, Mead & Co., Publishers.

It is always an agreeable surprise to have a biographical and historical work from the pen of a master in the science which occupied the life of the subject of his sketch. Indeed no other is capable of treating this class of biography. The book before us is one of the best of this class.

At the outset the author disclaims for his subject the creation *de novo* of an idea, but rather the adaptation of what was known before to practical use, by a combination with other known contrivances. With rare justice, Prof. Thurston mentions the early experiments of William Henry, of Pennsylvania, on the Conestoga Creek, in 1760. He probably originated the idea of the steamboat five years before Fulton was born. Both Fitch and Fulton visited Henry's house. In 1785, Fitch, at a special meeting of the Philosophical Society, was presented to the members. He spoke of Mr. Henry's claim to the first idea of propelling boats by steam.

Fitch lived on the banks of the Neshaminy, in Bucks County, Pa., when he tried the first successful experiments in using steam for the propulsion of boats. He was born in Connecticut. James Rumsey, of New York, also experimented in this direction in 1774. One of Fitch's boats, in April, 1790, made seven miles an hour. Captain Samuel Morey, of Orford, N. H., built a steamboat and ran from Orford to Fairlee, Vt. and back, in 1793. Fulton, the subject of the sketch, was born in Lancaster County, Pa., in 1760, and his career as artist, civil engineer, mechanic and statesman is ably sketched. Especially noteworthy was his invention of a diving boat, which was successful even when compared with modern apparatus of the time. He also suggested the screw propeller and devised submarine ordnance for firing through the water at the submerged part of a vessel's hull. He devised a twin-screw steamer in 1805. The book is well and fully illustrated, and is as extremely interesting as a narrative as it is valuable as a collection of well sifted historical data.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 17, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 17, 1892.

Mr. JOS. M. WILSON, President, in the chair.

Present, sixty-eight members and fourteen visitors.

Additions to membership since last report, eight.

The Secretary reported the resignations of Messrs. F. Lynwood Garrison and Otto C. Wolf from the Committee on Science and the Arts. The vacancies were thereupon filled by the election of Mr. Frank P. Brown for the unexpired term of Mr. Garrison, and Mr. Henry F. Colvin for the unexpired term of Mr. Wolf.

Mr. Carl Hering, delegate of the Institute to the Frankfort Electrical Exhibition, described some of the principal features of the Exhibition. (Mr. Hering's report will shortly appear in the *Journal.*)

Mr. James M. Dodge gave an oral account of the subject of coal storage, and illustrated, by means of a series of lantern slides, the substitution of the inefficient and comparatively expensive methods of the past by the vastly more efficient mechanical methods of storing and re-loading this product, which are now very generally used by the large companies engaged in the transportation of coal.

The Secretary's report was devoted principally to an account of the recent developments in the application of electricity to the welding and forging and shaping of metals.

Mr. John Carbutt described certain recent improvements in photographic methods, and exhibited some remarkable panoramic pictures forty-eight inches in length, made upon a curved celluloid plate; also several specimens of photographs of objects taken at a distance of several thousand feet by means of a peculiar combination of lenses devised for the purpose by Dr. Miethe, a German expert, and adapted to be used in a camera of ordinary size. A picture of the same subject and from the same standpoint, made, respectively, with an ordinary lens and the tele-photo lens of Dr. Mitehe, were shown side by side on the screen, and exhibited a surprising difference; the latter showing distinctly details that were quite invisible upon the former.

Adjourned.

WM. H. WAHL, *Secretary.*

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ALUMINUM: ITS MANUFACTURE AND USES FROM AN ENGINEERING STANDPOINT.

By ALFRED E. HUNT, C.E.,
President of the Pittsburgh Reduction Company.

Defining the science of engineering as the knowledge that has been accumulated of the relations to one another of force, matter, space, time and motion, and the practice of engineering as the art of applying this knowledge to the conversion of the materials and forces of nature to the use and convenience of man, we see that a broad field has still been left for the consideration of aluminum in the limiting clause in the title of the lecture to be given to you this evening.

Aluminum is now being made throughout the world upon a commercial scale only by processes of electro-deposition from fused electrolytes. In this country, the Pittsburgh Reduction Company and the Cowles Electric Smelting and

Aluminum Company are the only concerns manufacturing commercially and furnishing the American market with aluminum. In Great Britain, the Metal Reduction Syndicate, Limited, a branch of the Pittsburgh Reduction Company; and in Switzerland, the Aluminium Industrie Actien Gesellschaft, manufacturing at Neuhausen, using the water-power of the Falls of the Rhine; and in France, the firm of Bernard Brothers, now building a works at St. Michaels, and operating the Minet process, are, so far as the writer's knowledge goes, the only manufacturers now whose metal is met in the competition of the world's rapidly-growing market for aluminum. These statements need to be made preliminary to any considerations of the purity or other qualities of the commercial aluminum of the markets of the present day, for the reason that manifestly it will not be fair to take into consideration in treating of the commercial aluminum of to-day, the impure products made only on a small scale by the great number of processes being experimented upon, and by the many people working upon "The Aluminium Problem," as one of your lecturers, Prof. Richards, has pleased to call the present state of the art regarding the metal. The "problem" of extracting aluminum from some of its compounds which was first solved by Wöhler, in 1827, and later more completely by Deville, in 1854, has now been solved so many times and in so many ways that the task need hardly be dignified with the rank of a "problem" to-day. It takes very little skill with our present knowledge in the metallurgical arts to produce an impure grade of aluminum, as evinced by the many charlatans who are endeavoring to delude the public with their experimental exhibits and brilliant pages of prospectus or newspaper effusions. In the judgment of your lecturer, the aluminum "problems" of to-day are not so much the ways to produce the metal *most cheaply*, as the ways of utilizing the metal in the arts.

In the first of these problems, with great respect and with due deference to their opinions, I disagree with those who have spoken before me from this platform, in their expectation that cheaper methods of production are forthcoming. I am modestly, but firmly, of the opinion that the aluminum problem of the cheapest method of production has been practically solved in the electro-deposition of the metal from fused electrolytes, and that only in details will this method be improved or this part of the aluminum problem be better solved.

I am confident that the aluminum problem of *quality*, as determined by the purity of the metal, has been solved, and that upon a practical commercial scale, too, by several of the later methods of manufacture. At the works of Pechiney & Co., in France, from a date at least as far back as 1882, to my personal knowledge, M. Henri Brivet, their managing director, was enabled to manufacture regularly, by taking the utmost precautions and with carefulness and skill in manipulation as well as in all details of the Deville sodium process of production of aluminum, metal of over ninety-nine per cent. purity, an achievement, which, with the knowledge and state of the art of aluminum manufacturing then existing, and with the inherent difficulties of manufacturing pure aluminum by the sodium process, was worthy of the highest praise.

The impurities of the sodium-made metal are about one-half silicon and one-half iron. Both the Aluminium Company, Limited, of Oldbury, and the Alliance Aluminium Company, of New-Castle-on-Tyne, England, made metal and placed it upon the market in 1887 and 1888, of over ninety-nine per cent. purity; and Richards, in his work on *Aluminum*, edition of 1890, p. 246, refers to aluminum made by Grabau by a modification of the sodium process, in 1888, having 99·80 per cent. pure aluminum.

Both the Neuhausen concern and the Cowles, as well as the Metal Reduction Syndicate, Limited, of Patricroft, Lancashire, England, and the Pittsburgh Reduction Company, find no trouble by the electrolytic process in producing regularly metal with less than one per cent. of impurity. Indeed, the best results in quantity of output and regularity of working, and therefore in economy of manufacture, are when producing the purest aluminum, and it only requires further development of the manufacture of the aluminum oxide used as the ore and of the carbon anodes—matters which are perfectly practicable and possible—to obtain almost absolutely chemically pure aluminum by the electrolytic methods now in use. The Pittsburgh Reduction Company have made a good many tons of aluminum of over 99·90 per cent. purity; and I take pleasure in showing you and leaving for your museum a number of little ingots of aluminum containing no iron, copper or lead, and only eight-one-hundredths of one per cent. of silicon, having 99·92 per cent. pure aluminum, by the results of our chemist, Mr. J. O. Handy. With these achievements accomplished, I claim that the problem of quality of the metal as evidenced by its chemical composition has been solved, and solved with fully as much perfection as is the case in the metallurgy of any of the other metals. For with the same amount of care and precaution necessary to produce the so-called chemically pure metals of the markets to-day, by the electrolytic process equally pure aluminum can be produced, and in regular commercial practice aluminum is now being produced as pure in chemical composition as any of the other metals. I make this statement with care, and I think advisedly, being aware that other authorities, for whom I have great respect, have recently written to the contrary. The standard of purity of product obtainable in commercial aluminum having already been established by the processes now extant, and the advantages of the pure metal having become apparent, quite surely any new process to be successful in its competition for the market will have to produce metal of equal purity; a task that will in itself condemn many possibly competing processes. As aluminum is a much more difficult metal to reduce from its ores, under ordinary conditions, than is silicon or iron, almost any reagent or set of conditions that will result in the production of metallic aluminum, will alloy with it any iron or silicon that there may be present in the reagents used. This necessitates the materials used being almost chemically pure from silica, iron and other more easily reducible metals—a condition that will add fatally to the expense of many possible processes. The only alternative that seems to me possible is a method yet to be devised of cheaply purifying the metal alloyed with these substances. In fact, in this possibility of obtaining the metal alloyed and impure on a large scale and in a cheap way, and then purifying the aluminum, or a method of manufacture of the aluminum as a by-product of other operations, to my mind rests the only possible competition in process to the electro-deposition from a molten electrolyte.

In the economical reduction of the ores of most metals, one of the most difficult problems to be solved has been the wastage due to oxidation, volatilization or the solvent action of slags, or the impartial reduction or separation and collection of the metal, and its consequent waste in the scoria or refuse product. There are very few metals reduced to their pure state without a wastage of at least ten per cent. In the manufacture of aluminum as practised by the Pittsburgh Reduction Company, there is practically no waste whatever, the waste problem having been by the Hall process entirely solved.

I have already, in a previous lecture in February, 1891, before the Boston Society of Arts, stated that the cost of manufacture under the most favorable conditions with water-power and large output, would be approximately twenty cents per pound. Nearly one year's experience and careful study of the matter leads me to reiterate the statement then made, and to prophesy that the ingot metal will be made by the Hall process within the next few years at *a cost* of between eighteen and twenty cents per pound; the items of cost being about one-third for the ore, one-sixth for the expenditure of other materials than ore, one-third for the electrical current expended, one-twelfth for labor and superintendence, and one-twelfth for general expenses, interest and repairs.

Analyzing these items of cost, the ore will probably be the greatest item of expense in any successful process, and surely the oxide alumina is not only the richest and most easily prepared pure ore, but will prove one of the cheapest, if not the cheapest, of compounds from which to extract the metal. Any methods of cheaper production of alumina from clay or other more abundantly found mineral than bauxite (the hydrated oxide, containing from fifty-five per cent. to sixty per cent. alumina, and with less than ten per cent. silica and iron, the remainder being water), which can be laid down in Pittsburgh now in almost unlimited quantities at less than one-half cent per pound, will be equally applicable to the electrolytic as to any other process. Quite surely no difference here in the art will make an insurmountable barrier of cost for the electrolytic processes now in use to compete against. The expenditure for other reagents than the ore, for carbon and for chemicals, is now less than five cents per pound, with the Pittsburgh Reduction Company, and in the estimate can fairly be reduced to three cents per pound for a large plant, with most favorable arrangements made for its supplies. In the item of electrical power, there certainly may be room for a curtailment of cost; but even should this expenditure of electrical power be lessened one-half, or entirely done away with, heat alone being substituted as the energy for reduction of the ore, it will be difficult to conceive of a method that would not require a cost of at least one cent for this heat, which would be a saving perhaps of four cents per pound upon this item of electrical power. However, I feel confident that should such processes be devised, the increased expenditure for chemicals and other reagents, besides the amount quoted as necessary for the Hall electrolytic process, will nearly, if not quite, counter-balance the saving in electrical energy expended in the Hall process.

In the items of labor, superintendence and general expense, interest and repairs, there may be a small saving made by a process yielding metal more rapidly than by the comparatively slow electrolytic process.

I would, however, here call attention to the fact that our present experience leads me to believe that the items of labor and superintendence will quite surely be reduced to between two and three cents per pound of metal produced, and the amount required for general expenditure, interest and repairs to no larger than an equal expenditure, when the metal is made upon a very large scale. Again, these are necessary and inherent items of cost of any method of manufacture and the amounts that can be saved here by other possible means of manufacture, in my judgment, will prove very small indeed, surely not more than three cents per pound at greatest—an amount which I grant might, at some future time of competition, be a fatal one to the higher cost parties, but would not be such an amount as to lead to such startling changes in the selling prices of the metal, beyond what can be done by the electrolytic manufacturing interests, as one would be led to believe by the prophets who have gone before me. With the cost of manufacture being the ore at six cents per pound of metal made, and subject to almost any possible lowering of rate applicable to any other process, the power and materials used at eight cents, and the labor and all remaining expenses at between four and six cents per pound—cost items that I believe will be obtained gradually within the next few years by the electrolytic methods of production, I do not believe that there will be other methods devised to successfully compete with their totals of cost per pound. The average energy expended per pound of metal produced by the Pittsburgh Reduction Company is about twenty electric horse-power hours, or each electric horse-power hour of energy exerted upon the electrolyte yielding about twenty-two and seven-tenths grams of metal. Each month, by new experience, we are adding to this efficiency, and we confidently hope to make a gain of at least ten per cent. upon this record soon ; and I shall not be satisfied until this gain in efficiency shall reach at least twenty-five per cent. over present rates.

Our compound engines have a record of two pounds of coal per indicated horse-power hour, and with a twenty per cent. loss of potential in conversion of indicated horse-power into electrical—an estimate that is very liberal—we have twenty-four indicated horse-power hours per pound of aluminum produced, or an expenditure of forty-eight pounds of coal, which costs us eighty cents per ton at our works, or an expenditure for fuel of less than two cents per pound for the aluminum produced. Of course, to this has to be added labor, water (which we pump direct from the adjacent Allegheny River) and repairs; items which count up considerably upon a plant of only 600 horse-power; but with a large plant will bring the cost for power per pound of aluminum very low, and at a râte which will compare, especially if triple expansion and condensing engines are made use of, very nearly equally with the cost of the best water-powers. With water-powers, of which there are several in blocks of over 1,000 horse-power each, throughout the country, available at rates of from $8 to $15 per horse-power per annum, we can reckon on the cost of the electrical energy per pound of aluminum at between two and three-quarters and three cents per pound of metal made. Undoubtedly, the splendid power to be developed at Niagara will prove one of the best in the world for the manufacture of aluminum.

At these rates, a margin of nearly 100 per cent. is allowed in the estimate given above for the cost of the electric power, for a plant manufacturing aluminum by the Hall process under the most favorable conditions.

I do not, however, much fear the solution of this portion of the "aluminum problem," adversely to the interests of those of us who are engaged in the electrolytic method of its manufacture. I assure you that I do not thus confidently assert the courage of my convictions without a reason therefor. I have recently read over the historical portions of articles on aluminum in the world-famed *Journal of the Franklin Institute*, and with trepidation noted that it was possible to read the epitaph of all the methods of manufacture which started before the present ones of electro-deposition from molten electrolytes; many of them in the light of their day with even more of bright prospects of financial and metallurgical success than those now extant. I have noted that while Prof. Henderson was reading his able article before your Institute, in October, 1888, on aluminum, in which he speaks of the improved Deville sodium methods as the ones *de facto* supplying the world's aluminum of that day, the metal was then being regularly made by a cheaper method, and a commercial works within a month more were in operation, manufacturing upon a larger scale than ever before, by the electrolytic method that was to entirely supersede the improved sodium processes. Perhaps a similar fate hangs over this paper and its author. I am aware that precedent, as well as popular (and to a considerable extent, scientific) opinion is against me, and I can assure you that it would take much less courage for me to acknowledge the probability rather than to assert the improbability of a cheaper and better process, yet I am constrained to take the position that I have, with the hopes of turning the inventive and skilled, as well as the popular attention, to the fact that the next great source of cheapening aluminum will be a large demand for the metal, at present prices, sufficient to warrant outlay in plant to very greatly increase the capacity for manufacturing the metal. Aluminum will not be manufactured by any process at much less than at present, nor will it be sold at much lower rates, until the output be measured in tons, and not pounds, per day. The lowering of the market price of aluminum in the future will be gradual, and will be directly proportionate to the decrease in cost of manufacture, due to increased capacity of the manufactories.

Just as the wide-spread acceptance of inaccurate and misleading information regarding the properties of the metal hindered the development of the uses of aluminum in the arts, so at present the wide-spread forecasts of the metallurgical prophets, that the stars of new and much cheaper processes of manufacture are above the horizon of their horoscopes, without so much as vouchsafing us any tangible reasons therefor, are equally hindrances in that they discourage the expenditure of capital necessary to develop the manufacture of aluminum upon a scale sufficient to materially reduce the present manufacturing costs of the metal. The many brilliant new projects backed by scientific experts for manufacture of aluminum at wonderfully low costs, which flash out in the newspapers like meteors in the sky, and die out as rapidly, do much not only to hinder capital entering legitimate aluminum industries, but in deterring consumers from using or carrying any stock of a metal whose selling price they are led to believe may any day be reduced very much more than any possible gain their fabrication upon it may be to them.

In my judgment, the aluminum problems of by far the greatest moment yet remaining to be solved are in connection with the development of the uses of aluminum in the arts. Much has already been done in this matter, the demand for the metal increased tenfold over any previous year in 1891, yet very much more remains to be done. Undoubtedly much has yet to be developed in details in the economical production of aluminum; probably very few realize that more than your lecturer. At the same time, the problems involved in the development of the uses of aluminum in the arts have been under-estimated, and have not received the intelligent consideration that the importance of the subject warrants. The world has been centuries learning to use other metals; we have a right to expect more rapid development with the increased general knowledge of to-day, yet it will at best take time to open the entire field that the metal is destined to fill. Within the past ten years, there have been two popular widely-spread ways of solving this portion of the "aluminum problem," which are superficial, erroneous, and a hindrance to the true solution of the problem; the first assuming properties for the metal that it did not possess, proclaimed that aluminum would, as soon as it could be produced in sufficient quantities, replace all the other metals in the arts, not only for the special purposes where the higher grade metals are now used, but also for structural and building purposes to replace iron and steel; the second view of the subject (the natural reaction from the first erroneous one has become current within the past year or two, as the people began to use aluminum and found their ideals regarding it shattered) is to the effect that the metal has little or no use in the arts.

The reasoning for the first popular erroneous answer to the problems involved in the development of the uses of aluminum in the arts, was that aluminum was by far the most abundant of all the metals in its distribution in the earth's crust, and *consequently* should be the cheapest. Confusing the comparison of strength of materials, section for section with equivalent weights, forgetting to take into account its low elastic limit and modulus of elasticity, or modulus of resilience, or its lack of rigidity under compression strains or its natural softness; but noting that the metal withstood the ordinary atmospheric and other usual conditions of corrosion with considerable efficiency over other metals commonly used in the arts, the enthusiastic conclusion was reached that we were rapidly leaving the "steel age" as we had the "iron age" before it, and were advancing upon the "aluminum age," "where this wonderful metal should supersede all others for almost all the uses of mankind." It is surprising that some of the hopeful ones did not propose to mould up the clay banks into buildings and railroads and other useful contrivances, and turn on the electric current and produce the aluminum structures *in situ*.

As instances of the second view of the case that I am sorry to say has become quite fashionable of late, as shown by the frequent publications in trade journals, a writer in a recent German publication disappointed in his ideals regarding the solubility of the metals in acids, and finding that aluminum could not be used as a substitute for platinum in acid stills, immediately jumps to the conclusion (and publishes his conclusions broadcast) that the metal is entirely unsuitable for culinary utensils, seemingly forgetting that cooking operations are not conducted in muriatic, nitric, or even in sulphuric acids, as dressings or gravies, and not considering it necessary to investigate the action of these acids or their salts upon the metal in quantities, and under conditions similar to those the metal would in any likelihood be subjected to in actual use in culinary utensils.

Another writer has gone through a long list of experiments, heading his table of results "Solubility of Aluminum in Acids," using aluminum *foil* and finding that in from two to four days the foil was dissolved in from one to ten per cent. solutions in water or many organic acids, such as formic, acetic, butyric, lactic, tartaric, citric, oxalic, palmitic, stearic, gallic, salicylic, carbolic, boric, etc., he wisely proclaims that these results show that this metal is unfit for canning materials, cooking utensils or any chemical laboratory purposes. This writer forgets to investigate the differences between foil and thicker plates before drawing his conclusions, nor did he inquire as to the action of these same reagents upon equally thin foil sheets of other metals, now used for the operations he describes. Had he done so, he would have found that in the sections used in utensils of other metals, aluminum withstands the action of all the reagents mentioned as well as do the metals now in common use; and as for the action of ordinary solutions on thin foil, tin, iron and copper are fully as rapidly acted upon as is aluminum. Aluminum has neither taste nor odor, nor are its salts (in small quantity) especially poisonous, as are the salts of other metals now more commonly used.

Aluminum is not much more acted upon than is tin, copper or silver by salt water, and even by such solutions in vinegar as the metal is liable to be subjected to in ordinary culinary vessels. The salts of tin or copper thus dissolved are very poisonous; but not only are the aluminum salts that are formed less in amount, but the acetate of aluminum formed resolves itself on boiling into either an insoluble subacetate or into pure alumina, neither salt having either taste or injurious toxic action. For these reasons, quite surely aluminum will have a large future for cooking utensils.

Aluminum cooking utensils have been used in my own home for the past two years, almost altogether, being subjected to all of the usual materials that varied household uses subject them to, including plenty of good soap and water and scrubbing; and none of the vessels are in the least corroded. Aluminum spoons have been subjected to treatment with vinegar in comparison with silver spoons, and have withstood the ordeal equally as well, and are in constant use in my own home.

A careful and intelligently chosen course regarding the development of the use of aluminum in the arts, the medium of the two above referred to, determining the uses for which the metals shall be utilized in the arts from a reasonably accurate knowledge of the properties of the metal and the requirements that will be demanded of it in its proposed applications, is the task to be accomplished in solving this portion of the "aluminum problem." Considerable has already been done in this work, and fortunately the problem is applicable to a multitudinous subdivision among the world's workers. Nothing is gained in advancement of the knowledge, welfare or skill in the arts, in the world's rapidly developing needs, except at somebody's cost.

> "Not a truth has to science or art been given,
> But brows have ached for it and souls have toiled and striven."

There is much yet to be done along these lines in solving this portion of the "aluminum problem." I believe this field to be a richer one and will yield better results to the successful investigators of the future than the one of endeavoring to find a new and more economical method of manufacture of the metal.

The late James Nasmyth epigrammatically said that "engineering is common sense applied to the use of materials;" had he added the word *intelligent*, his definition seems to me would be well nigh perfect, and that portion of my subject which referred to the "uses of aluminum from an engineering standpoint" could be stated in terms of this definition as follows: *common sense applied to the intelligent use of aluminum.*

It is along these lines that I wish to make a plea for the metal to-night, that the public interest that is now so widespread, and the work of the many inventors who are now so earnestly struggling with the "aluminum problem" be turned in this seemingly new direction of attacking the metal from an engineering standpoint—that is, exercising "common sense applied to the intelligent use of the metal."

The principal impurity of the commercially pure aluminum of to-day is silicon, which exists in two forms, one seemingly combined with the aluminum, as combined carbon exists in white pig iron, and the other in an allotropic graphitoidal modification. These two forms of silicon seem to exert somewhat different effects by their presence in the aluminum; the combined form of the element rendering the metal much harder than the graphitoidal variety. The combined silicon ordinarily preponderates, being fifty-five per cent. to eighty per cent. of the total silicon in the metal of ninety-nine per cent. purity made by the Pittsburgh Reduction Company. The graphitoidal silicon is separated on dissolving aluminum in hydrochloric acid as a black insoluble residue, and appears like graphitoidal carbon on similarly treating gray cast iron. In fact, it has been mistaken for carbon by many superficial or ignorant observers. Carbon does not unite with aluminum except at very high temperatures, and its influence seems to be to make the metal very brittle. Metal containing carbon can readily be told by its abnormal crystalline and peculiar colored fracture.

In the electrolytically made commercially pure aluminum of to-day, the only other impurity is iron, which, if it exists in larger quantity than five or at most ten–one-hundredths of one per cent., is the result of carelessness in manufacture, or the selection of needlessly impure alumina ore or carbon anodes. The presence sometimes found of copper or lead in any quantity in the metal, is the result of needless contamination with these elements in the preparation of the ore or the carbon anodes, or in the manipulation of the pots. By allowing the pots to run for a considerable time without ore, and with a high current and very hot electrolyte as sometimes occurs in careless working of the pots, metallic sodium has been alloyed with aluminum in noticeable percentages. Upon placing such metal in hot water, the sodium will be rapidly dissolved out with considerable effervescence, and the pure metal left spongy, honey-combed and weak.

For many purposes, the purest aluminum cannot be so advantageously used as that containing three per cent., or even four per cent. of impurity, as the pure metal is very soft, and not so strong as the less pure. It is only where extreme malleability, ductility, sonorousness, or non-corrodibility is required that the purest metal should be chosen. For most purposes a small percentage of other elements than silicon and iron are advantageously added in producing hardness, rigidity and strength. Titanium, chromium and copper can readily and cheaply be added, and are constituents that will not detract from the non-corrodibility of the metal as much as do these natural impurities that come from the ore and apparatus—additions that will give the aluminum a better color and greater strength and hardness, with proportionately less sacrifice of malleability, ductility, etc.

The properties of aluminum which will probably give it the greatest availability in the arts, are:

(1) Its relative lightness.

(2) Its non-tarnishing quality as compared with many other metals; aluminum not being acted upon by sulphur fumes at all, and being very much more slowly oxidized by moist atmospheres than most of the metals.

(3) Its extreme malleability.

(4) Its easy casting qualities.

(5) The influence of the metal in various alloys will give it advantages, some of which I will try to enumerate and call to your attention.

(6) Its high tensile strength and elasticity when weight for weight of the metal is compared with other metals, and especially when alloyed with a small percentage of titanium, silver or copper and properly worked by being rolled or hammered or otherwise drawn down.

(7) Its high specific heat and electrical and heat conductivity.

Unfortunately, aluminum is not, section for section, as has been widely claimed, comparatively a very strong metal. It is only about as strong under tensile strain, section for section, as cast iron, and has less than one-half the strength of wrought iron under ordinary conditions. Under compression, the metal, unfortunately, has a very low elastic limit, although its extreme ductility allows the metal to flow on itself so freely as to make it for special purposes a very safe metal to use in compression. I show a series of cylinders of one and one-half inch diameter, which have each had a compressive strain of 200,000 pounds applied to them, together with the result of a compression strain of 180,000 pounds upon similar cylinders of cast iron.

The same remark applies to transverse tests on aluminum. It is not a rigid metal at all, and bends under transverse strains very readily. I append a table of results which, from our experience, I believe will show about the average tensile and compressive tests of commercially pure aluminum, unannealed:

		Pounds.
Elastic limit per square inch in tension	(castings),	5,000
	(sheet),	12,000
	(wire), 16,000 to	30,000
	(bars),	10,000
Ultimate strength per sq. in. in tension	(castings),	15,000
	(sheet),	24,000
	(wire), 30,000 to	65,000
	(bars),	28,000
		Per Cent.
Percentage of reduction of area in tension	(castings),	10
	(sheet),	25
	(wire),	40
	(bars),	20
		Pounds.
Elastic limit per square inch under compression in cylinders, with length twice the diameter,		3,500
Ultimate strength per square inch under compression in cylinders, with length twice the diameter,		12,000
The modulus of elasticity of cast aluminum is about,		11,000,000
" " " forged " "		15,000,000
" " resilience of cast " "		·1600
" " " forged " "		·2200

Under torsional stress in Thurston's torsional machine, the metal has much lower modulus of rigidity than iron or steel; its maximum shearing stress in castings being about 12,000, and in forgings about 16,000, being about that of pure copper. The angle of torsion is about equal to that of the softest steel.

The following tables of tests are of results obtained since those published in the article on "The Properties of Aluminum," by Alfred E. Hunt, John W. Langley and Charles M. Hall, published in the *Transactions of the American Institute of Mining Engineers*, vol. xiii.

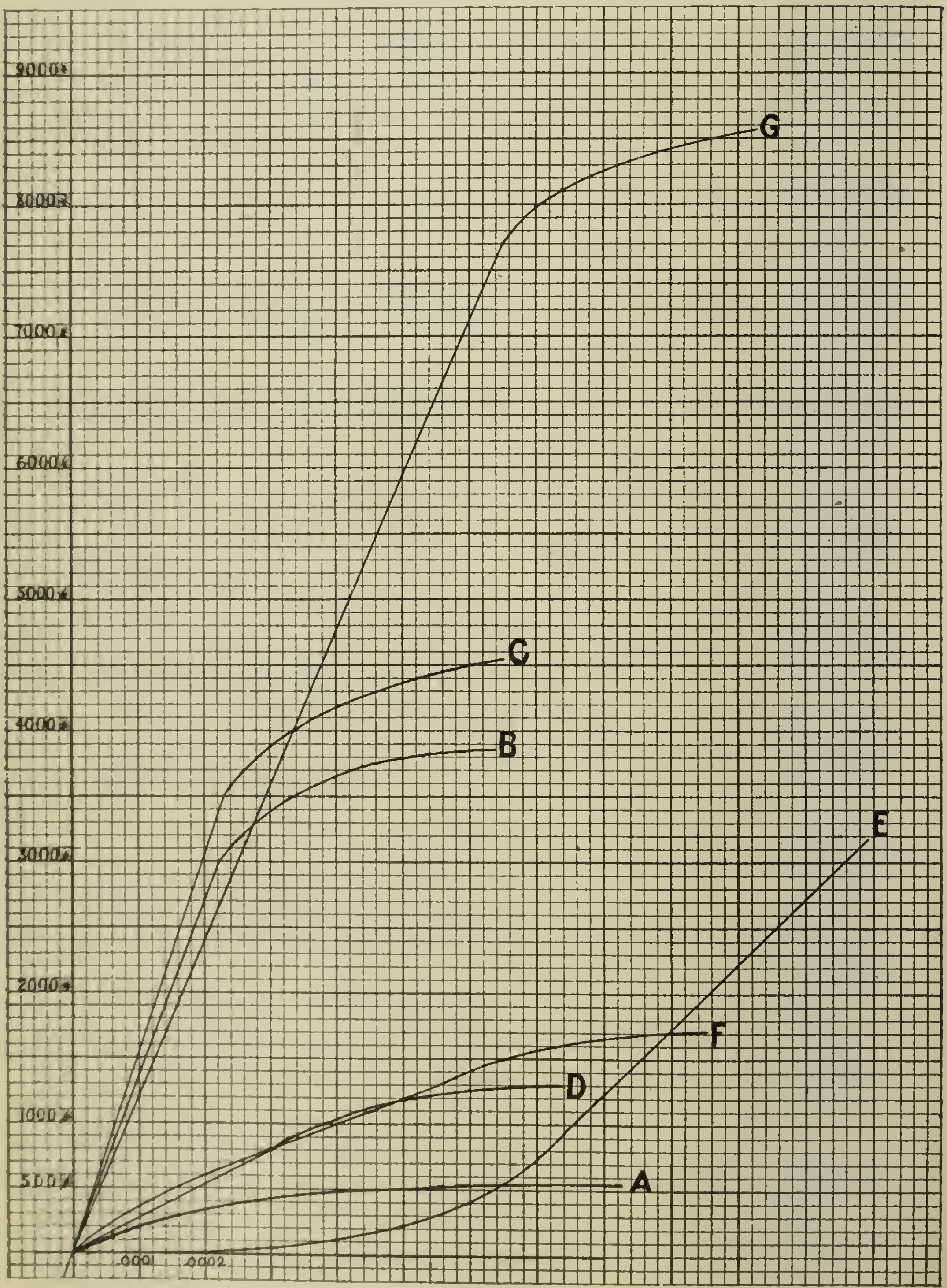
TABLE I.—TENSION TESTS.

	Elastic Limit. Pounds per Sq. In.	Tensile Strength. Pounds per Sq. In.	Reduction of Area. Per Cent.	Elongation in 8 Inches. Per Cent.	Modulus of Elasticity.	Modulus of Resilience.	Character of Fracture.	REMARKS.
Cast aluminum rods ½ inch, diameter A, ...	—	15,334	4·70	3·9	11,000,000	—	Granular.	Very pure soft metal annealed.
" " 1¼ " B, ...	2,268	11,849	2·50	2·25	10,084,000	0·2127	Granular.	" " "
" " 1½ " C, ...	2,026	11,870	0·40	3·50	8,532,631	0·2005	Granular.	" " "
" " ½ " D, ...	5,128	12,820	10·30	1·50	15,194,074	0·0721	Granular.	" " "
" " mean of above, ...	3,225	13,011	4·40	2·78	11,270,268	0·1618	Granular.	" " "
Forged aluminum rods ½ inch, diameter E, ...	9,856	26,901	0·70	0·78	15,460,392	0·2602	Granular.	" " "
" " 1¼ " F, ...	6,110	17,705	3·80	2·50	9,400,704	0·1654	Granular.	" " "
" " 6-10 " G, ...	—	20,4 0	10·00	2·34	—	—	Granular.	" " "
" " mean of above, ...	7,983	21,270	4·80	1·15	12,430,580	0·2128	Granular.	" " "
Drawn aluminum wire, No. 16, B. & S. Gauge, . . .	19,430	65,320	14·20	7·10	19,700,000	—	Silky.	Cold drawn metal 98 per cent. pure.
" " No. 16, " . . .	10,500	32,310	15·30	8·50	—	—	Silky.	" " " annealed
Aluminum casting hardened with 3 per cent. copper,	6,132	15,640	8·66	—	—	—	Granular.	
" " drop forged, ...	9,220	18,310	5·30	3·50	—	—	Granular.	
" sheet, No. 20, B. & S. Gauge, ...	6,590	23,510	9·60	2·10	—	—	Silky.	Metal of 97½ per cent. pure, remainder mostly silicon.
" " No. 10, "	9,980	29,650	4·10	1·80	—	—	Granular.	Metal cold rolled 98 per cent. pure.

TABLE III.—TORSION TESTS.

	MOMENT OF TORSION. INCH POUNDS.		ANGLE OF TORSION. DEGREES.		EXTENSION OF OUTER FIBRE.			SHEARING STRESS.			
	Elastic Limit.	Maximum Strength.	Elastic Limit.	Maximum Limit.	Elastic Limit.	Maximum Extension.	Final Extension.	Elastic Limit.	Maximum Stress.	Modulus of Rigidity.	Elastic Resilience.
Cast Aluminum 0·751 inches diameter, .	—	1114·76	—	110°	—	·166	·1660	—	13,473	—	—
Forged " 0·751 " .	666·49	1274·	1·56°	260°	·00003	·738	·9120	8163·	15,285	843,658	8·99
Cast " 0·980 " .	—	2548·	—	72·5°	—	·0753	·0735	—	—	—	—
Forged " 0·980 " .	1433·	2942·	5·0°	157·5°	·0003	·317	·4490	7802·	16,022	186,133	62·34
Cast " 0·625 " .	—	478·	—	109·3°	—	·1601	·1601	—	10,133	—	—
Forged " 0·620 " .	478·	755·	4·37°	57·5°	·00024	·048	·1490	10133·	16,593	434,318	18·15
Cast " 0·760 " .	1036·	1115·	2·18°	36·25°	·00007	·0193	·0193	9045·	13,149	869,849	19·67
Forged " 0·760 " .	319·	1194·	1·25°	168·75	·0 002	·359	·6550	3757·	14,089	461,594	3·49

TABLE II.—CURVES OF EXTENSION OF SAMPLES MARKED *A, B, C, D, E, F, G,* OF TABLE I.



It will be noted that the tensile strength of aluminum wire runs up very considerably over that of the rolled metal. This is due to the peculiar property of aluminum to harden under work. The metal requires frequent annealing in rolling; and if it is to be drawn into wire with as little annealing as possible, the tensile strength is increased very considerably. This property of the metal is increased, especially if the aluminum is alloyed with a small percentage of copper, titanium or silver.

It is perfectly feasible to produce a wire of aluminum alloyed with a small percentage of silver, titanium, or copper, which will have a tensile strength of 80,000 pounds to the square inch, and which will have, weight for weight with copper wire, an electrical conductivity of 170 to that of copper being 100. When it is taken into consideration that the copper will only have a tensile strength at maximum of (say) 30,000 pounds per square inch, against the 80,000 pounds strength of the aluminum-titanium alloy, and when the further fact that iron or soft steel wire has only a conductivity of seventeen in the same scale, and has a less, or at most only an equal tensile strength per square inch with the aluminum-titanium alloy, a wide field for usefulness for electrical conductors seems opened for the metal, even at present when the price of the wire of aluminum-titanium alloy will necessarily be considerably higher; but when such an alloy can be produced in fine wire at a price of (say) fifteen times that of the iron wire, pound for pound, then as the section can be reduced the aluminum-titanium alloy will be the cheapest as well as the most advantageous for electrical conductors.

Two things, however, should always be borne in mind in considering the applicability of aluminum for given purposes in the arts. The first is that the properties of the metal are very considerably changed as regards strength, tenacity, hardness, rigidity and color, by alloying it with small percentages of other metals, conditions that do not materially change the specific gravity of the metal. The second is the relative weight of aluminum; taking the tensile strength of aluminum in relation to its weight, it is in plates as strong as steel at 80,000 pounds per square inch ultimate strength, and in cold drawn wire as strong as steel at 180,000 pounds ultimate.

The specific gravity of aluminum, of course, is one of its most striking properties; it varies from 2·56 to 2·70. The weight of a given bulk of aluminum being taken as one, wrought iron is 2·90 times as heavy; structural steel is 2·95 times; copper 3·60 times; ordinary high brass, 3·45 times; nickel, 3·50 times; silver, four times; lead, 4·80 times; gold, 7·70 times; and platinum 8·60 times as heavy. Most woods that would be used for structural purposes are about one-third as heavy as aluminum.

The specific gravity of aluminum is 2·56 in ingots and 2·64 in forged bars.

A cubic inch of cast aluminum weighs ·092 pound; of rolled sheet metal, ·098 pound.

	Weight in Pounds of one Cubic Foot.	*Tensile Strength per Square Inch.*	*Length of Bar in Feet able to support its own Weight.*
Cast iron, ...	444	16,000	535
Ordinary gun bronze, . .	525	36,000	9,893
Wrought-iron plates, . . .	480	50,000	15,000
Aluminum plates, ...	165	26,000	23,000
(cold rolled),	168	35,000	39,615
(cast), . . .	160	15,000	13,231
(forged), . .	165	20,000	17,700

Wherever momentum is to be overcome, as in the reciprocal parts of many forms of machinery, aluminum can be advantageously used.

For valves, for structural purposes, and for machinery where lightness is a prime factor and where the wear due to the softness of the metal in bearings can be avoided by bushing, and its pliability can be overcome by properly designed sections and by using metal hardened by alloying and by cold-rolling, drop-forging, or otherwise stiffening it up, the metal can be used advantageously and deserves further consideration.

Aluminum does not oxidize seriously so as to interfere at all with the strength of thin sections of the metal as does iron or steel; the thin film of oxide which covers the surfaces of the metal which have been long exposed to moist atmosphere seems to prevent its being further acted upon. But it does give a surface tarnish to the metal which cannot be rubbed off with the usual metal polishing compounds without interfering with the surface of the soft metal. This, however, can be removed by rubbing with a flannel rag which has been immersed in a two per cent. solution of hydrofluoric acid and then again rubbing up the polish with a rag saturated with carbon oil. Special aluminum polishes have been devised which work very efficiently. When properly cared for, polished surfaces can thus be kept bright for a remarkably long time.

As compared with most metals, pure aluminum, under ordinary circumstances, withstands the action of wind and weather exceedingly well; and many uses to which the metal is now being successfully applied are based upon this fact. The presence of silicon in aluminum materially detracts from its power to withstand corrosion due to atmospheric influences. Metal with four per cent. or five per cent. of silicon very soon collects a thick coating of oxide upon it, if severely exposed. The fact that pure aluminum is not severely acted upon by boiling water or by steam has led to its successful use as a packing or gasket in steam connections, where lead and similar metals have been rapidly cut out, as in parts of steam and water pumps and difficult steam joints.

Aluminum is not acted upon by carbonic acid or carbonic oxide, or sulphuretted hydrogen, at any temperature less than 600° F., and these facts will undoubtedly lead to its application for many new purposes in the future.

Aluminum is found to withstand the action of organic secretions better even than silver, and for many forms of surgical instruments and apparatus such as suture wires and tracheometer tubes, the metal is already receiving very wide use. Many surgeons are having their instrument cases made of aluminum; it having the advantage that they can safely be washed clean with antiseptic solutions. It may be well, however, to say here that perspiration in handling polished aluminum does tarnish the metal, and that aluminum, like other metals, cannot retain a high polish with frequent handling. The natural acid solvent for aluminum is hydrochloric acid. Solutions of the strong caustic alkalies, chlorine, bromine, iodine, and fluorine rapidly corrode aluminum. Ammonia gas has very little action on the metal, except to turn it a gray color. Strong aqua ammonia has a slight solvent action upon it.

I take pleasure in exhibiting two plates of about six inches square each, one of aluminum and one of copper, which have been nailed upon the wooden sides of a schooner that has made a trip from New York to the West Indies and back, and were immersed in the sea water together for four months. The sheets weighed one pound two and three-quarters ounces avoirdupois for the copper sheet, and five and three-eighths ounces for the aluminum sheet; neither sheet lost an appreciable amount by the service. The original thickness of the sheets was 0·087 inch each, and now is 0·087 inch and 0·086 inch, for the aluminum and copper, respectively, showing that the copper sheet corroded the most under equal treatment. Unfortunately for the advantageous use of aluminum as a sheathing for ships, however, the barnacles seem to thrive on the aluminum sheet, a satisfactory evidence of the relative non-corrodibility of the metal, but not of its availability for certain marine purposes.

For structural purposes under water, where metals are required, aluminum seems to be especially adapted to replace the more easily corroded cast and wrought iron and steel now in general use for such purposes. For liners and shims upon masonry foundations, aluminum is well adapted, as it flows sufficiently to allow equal bearings on all parts, and is less easily cut out then lead, and much more durable than tinned iron sheets which are now in general use under heavy structures of metal resting on metal shims on masonry.

Aluminum sheets will make a much more durable and satisfactory roofing than sheet copper now generally used in valuable buildings.

Under heat the coëfficient of linear expansion of three-eighths inch round aluminum rods of ninety-eight and one-half per cent. purity gave results as follows:

$$\left.\begin{array}{l}\cdot00002295\\ \cdot00002289\\ \cdot0000206\\ \cdot0000230\end{array}\right\}\text{ per degree Centigrade,}$$

between the freezing and boiling points of water; that of iron being ·0000122, tin ·0000217, copper ·00001718.

The coëfficient being obtained in the usual way by dividing the difference in length of the test bars at two given different temperatures, by the product of the original length of the bars times the difference in temperatures.

The specific heat of aluminum, according to the experiments of Prof. J. W. Richards, is ·02143, water being taken as one.

The coëfficient of thermal conductivity of aluminum, obtained by the method of Wiederman and Franz, silver being taken as 100 and copper as 73·6, is 37·96 (unannealed aluminum); annealed aluminum, 38·87.

Aluminum stands fourth, being preceded only by silver, copper and gold, as a conductor of heat as well as electricity. One yard of annealed aluminum wire of ninety-eight and one-half per cent. purity, ·0325 inch diameter at 14° C., having ·05484 of an ohm resistance; a yard of pure copper wire having a resistance of ·0315 under like conditions. The electrical conductivity of a standard section of pure silver being taken at 100, an equal section of copper also at 100, pure gold at 78·0, an equal section of pure annealed aluminum has an electrical conductivity of about 54·20.

Pure zinc,	29·90
High brass,	21·50
Pure tin,	15·45
Soft ·10 carbon open hearth steel,	12·00
Platinum,	10·60
Lead,	8·88
Nickel,	7.89
Antimony,	3·88

Authority, Lazare Wiler. Communication to the Société Internationale des [illegible]

This relatively high electrical conductivity when equal weights are taken will undoubtedly prove a factor of importance in developing electrical uses for aluminum.

The electrical conductivity of aluminum is increased fully five per cent. by carefully annealing even the ordinary soft wire, and with hard drawn wire the conductivity is increased by annealing nearly ten per cent.

Pure aluminum has no polarity, and indeed the commercial metal in the market is practically non-magnetic.

Pure aluminum is very sonorous, and its tone seems to be improved by alloying with a small percentage of silver or titanium. For the sounding boards of musical instruments, aluminum has been proven to be well adapted.

Pure aluminum, when properly treated, is a very malleable and ductile metal. It can readily be rolled into sheets ·0005 of an inch thick, or be beaten into leaf nearly as thin as gold leaf, or be drawn into the finest wire. Pure aluminum stands third in the order of malleability, being exceeded only by gold and silver; and in the order of ductility, seventh, being exceeded by gold, silver, platinum, iron, soft steel and copper. Both malleability and ductility are greatly impaired by the presence of the two common impurities, silicon and iron.

Aluminum can be rolled or hammered cold, but the metal is most malleable at, and should be heated to, between 350° and 400° F., for rolling or breaking down from the ingot to the best advantage. Like silver and gold, aluminum has to be frequently annealed, as it hardens up remarkably upon working. Due to this phenomenon of hardening during rolling, forging, stamping, or drawing, the metal may be turned out very rigid in finished shape, so that it will answer excellently well for purposes where the annealed metal would be entirely too soft, or too weak, or lacking in rigidity to answer. Especially is this true with aluminum alloyed with a small percentage of titanium, copper or silicon. It can be safely stated, as a general rule, that under similar conditions the purer the aluminum, the softer and less rigid it is.

Aluminum can be annealed by heating and allowing to cool gradually; the best temperature is just below the red heat. Thin sections can be annealed by heating in boiling water.

Aluminum can be easily and readily welded by the apparatus of the Thomson Electric Welding Company.

Until very lately the lack of methods for successfully soldering aluminum was among the greatest drawbacks to its introduction for many purposes. Thanks to your townsman, Mr. Jos. Richards, we have a cheap solder that works satisfactorily. I take pleasure in exhibiting soldered samples and pieces of the solder. The trouble with any solder is to get it to flow, for not only has the natural disinclination of most solders to spread over aluminum to be overcome, but also, due to its very high heat conductivity, the heat of the solder is withdrawn with such rapidity as to cause the solder to "freeze" before flowing sufficiently. This difficulty has been overcome in most cases by the use of a very hot soldering iron. In the most difficult places, the use of crystals of chloride of silver has been found to aid the flow of the solder. This use of chloride of silver for this purpose is subject to the U. S. Patent, No. 375,875, of Messrs. Page and Anderson, of Waterbury, Conn.; their patent rights being for sale by W. H. Pierce, 37 Platt Building, Waterbury, Conn.

Sound castings of aluminum can be made in dry sand moulds or in metal chills. As an evidence of this, I take pleasure in exhibiting a tea-kettle cast from the metal by the Auburn Hollow Wax Company, of Auburn, N. Y. It, however, requires some experience and expertness on the part of the founder to master the peculiarities of the metal, before perfectly sound castings can be uniformly made. The aluminum should not be heated very much beyond the melting point; otherwise it seems to absorb gases, which remain in the metal, preventing sound castings. In small quantities the metal can be best melted in plumbago crucibles; but in large quantities it can be more economically melted in a reverberatory furnace with alumina or magnesia brick sides and alumina bottom. The furnace should have a tap-hole for drawing off the liquid metal into carbon-lined ladles. In no case need the metal be covered with a flux to assist in the fusion or to form a covering of slag. In fact, owing to the metal's lightness, the presence of any flux will tend to unsoundness, due to particles of it becoming entangled in the castings, while impurities may perhaps be added to the metal by the action of the flux on the lining of the melting vessel. The shrinkage of seventeen–sixty-fourths of an inch per foot, which aluminum has, is considerably more than that of brass, which is about three–thirty-seconds of an inch per foot.

Undoubtedly, one of the greatest uses for aluminum in the arts will be in the form of alloys with other metals. Aluminum in proportions of a small percentage added to very many different metals gives valuable properties. Among these alloys is, of course, aluminum bronze. The alloys of from two and one-half per cent. to twelve per cent. aluminum with copper have so far achieved the greatest reputation. With the use of eight per cent. to twelve per cent. aluminum in copper, we obtain one of the most dense, finest grained and strongest metals known, having remarkable ductility as compared with its tensile strength, A ten per cent. aluminum bronze can be made in forged bars with 100,000 pounds tensile strength, 60,000 pounds elastic limit, and with at least ten per cent. elongation in eight inches. An aluminum bronze can be made to fill a specification of even 130,000 pounds tensile strength and five per cent. elongation in eight inches. Such bronzes have a specific gravity of about 7·50, and are of a light yellow color. For cylinders to withstand high pressures, such bronze is probably the best metal yet known.

The five to seven per cent. aluminum bronzes have a specific gravity of 8·30 to 8 and are of a handsome yellow color, with a tensile strength of from 70,000 to 80,000 pounds per square inch, and an elastic limit of 40,000 pounds per square inch. It will probably be bronzes of this latter character that will be most used; and the fact that such bronzes can be rolled and hammered at a red heat with proper precautions will add greatly to their use. Metal of this character can be worked in almost every way that steel can, and has for its advantages its greater strength and ductility and greater power to withstand corrosion, besides its fine color. With the price of aluminum reduced only a very little from the present rates, there is a strong probability of aluminum bronze replacing brass very largely.

A small percentage of aluminum added to Babbitt metal gives very superior results over the ordinary Babbitt metal. It has been found that the influence of the aluminum upon the ordinary tin-antimony-copper-Babbitt is to very considerably increase the durability and wearing properties of the alloy. Under compressive strain, aluminum-Babbitt shows to be a little softer than the ordinary Babbitt. A sample, one and one-half inches diameter by one and one-half inch high began to lose shape at a pressure of 12,000 pounds. A similar sample of the same Babbitt metal without the addition of the aluminum (having a composition of 7·3 per cent. antimony, 3·7 per cent. copper and eighty-nine per cent. tin) did not begin to lose its shape until a compressive strain of 16,000 pounds had been applied. Both samples have stood about an equal strain of 33,000 pounds. In comparative tests of the ordinary Babbitt metal and the aluminum-Babbitt metal, the latter has given very satisfactory results. At the works of A. W. Cadman & Co., 63 Water Street, Pittsburgh, a crank-pin bearing of a thirty horse-power engine with the ordinary Babbitt metal required resetting about every three days; and after inserting in the bearing aluminum-Babbitt strips of about a half-inch width upon the face, dove-tailed in alternately in the brass bearing, the same bearings ran under similar work for two months without requiring any attention; and when examined at the end of two months, the crank pin was found to have become very much smoother than it was before the aluminum-Babbitt had been inserted. Mr. Cadman recommends dove-tailing in the strips of Babbitt, for the reason that it gives equal bearing all over the surface. Another advantage of this Babbitt is its extreme malleability. It can be hammered out to a thin edge without cracking, whereas the ordinary Babbitt is not at all malleable. An advantage of this is that for bearings, with aluminum, the

Babbitt can be rolled into shape for inserting in the dovetailed recesses, which can be cut and drifted out at a very small expense, and the amount of Babbitt required is reduced to a minimum.

Aluminum is also being used very successfully in steel castings, and has added very considerably to the progress which has been made within the last two years in obtaining sound steel castings. A large number of steel casting companies are regularly using the metal aluminum in quantities of from one-half pound to several pounds of aluminum to the ton of steel. In the manufacture of ordinary steel ingots by the open-hearth and Bessemer processes, it has lately been shown in the article on "Aluminum in Steel Ingots," by Prof. J. W. Langley, at the January, 1891, meeting of the American Institute of Mining Engineers, that the use of aluminum in small proportions (from one-third to three-fourths of a pound of aluminum to the ton of steel) has proved to be an economical success, preventing blowholes and unsound tops of ingots.

Alloys of aluminum with copper in proportion of from two per cent. to fifteen per cent. have been advantageously used to harden aluminum in cases where a more rigid metal is required than pure aluminum. Copper is one of the most common metals used at present to harden aluminum. A small percentage of copper decreases the shrinkage of the metal and gives alloys that are especially adapted for art castings. The remainder of the range, from fifteen per cent. copper up to over eighty-five per cent., give crystalline and brittle alloys of no use in the arts; which are of a grayish-white color, up to eighty per cent. copper, where the distinctly yellow color of the copper begins to show itself.

With the exception of lead, antimony and mercury, aluminum unites readily with all metals; and many useful alloys of aluminum with other metals have been discovered within the last few years, and I prophesy that many more will be found within the next few years. I consider this field as one of the most promising for investigation of any of the "aluminum problems." The useful alloys of aluminum so far discovered are all in two groups, the one of aluminum with not over fifteen per cent. of other metals, the other of metals containing not over fifteen per cent. of aluminum; in the one case, the other metals imparting hardness and other useful qualities to the aluminum, and in the other, the aluminum giving useful qualities to the other metals.

The alloy of a small percentage of silver with aluminum to harden, whiten and strengthen the metal, gives a metal especially adaptable for many fine instruments, tools and for electrical apparatus, where the work upon the product and its convenience are of more consequence than the increased price due to the addition of the silver. The silver lowers the melting point of aluminum and gives a metal susceptible of taking a fine polish and making fine castings.

Titanium and chromium can be readily alloyed with aluminum according to methods devised and patented by Prof. John W. Langley. This will probably prove to be the most valuable means of hardening aluminum; a small percentage of titanium rendering the metal, under work, very rigid and yet elastic at the same time. Chromium is the best metal for hardening aluminum castings; the triple alloy being best adapted where a very hard and yet elastic material is required.

More or less useful alloys have been made of aluminum with bismuth, nickel, cadmium, magnesium, manganese and tin, these alloys all being harder than pure aluminum; but it is by combinations of these metals, with additions, perhaps, of copper, lead and antimony, that alloys of most value have so far been discovered. Some are additions of only one per cent. to two per cent. of aluminum.

The modifications of pewter, britannia, white metal, delta metal, and the like, with additions of aluminum, have shown very useful qualities and will add very considerably to the demand for aluminum in the near future.

The following alloys have recently been found useful: Nickel-aluminum, composed of twenty parts nickel and eight parts aluminum, used for decorative purposes; rosine, composed of forty parts nickel, ten parts silver, thirty parts aluminum, and twenty parts tin, for jewellers' work; sun-bronze, composed of sixty parts cobalt (or forty parts cobalt), ten parts aluminum, forty (or thirty) parts copper; metalline, composed of thirty-five parts cobalt, twenty-five parts aluminum, ten parts iron, and thirty parts copper.

Besides these, Prof. Emmens, the well-known inventor of Emmensite explosives, has great hopes for an alloy of aluminum-bronze and nickel for a gun metal.

Prof. Robert Austin has discovered a beautiful alloy, containing twenty-two per cent. aluminum and seventy-eight per cent. gold, having a rich purple color with ruby tints.

The addition of from five per cent. to fifteen per cent. aluminum to type metal composed of twenty-five per cent. antimony and seventy-five per cent. lead, makes a metal giving sharper castings and a much more durable type.

To ordinary brass, the addition of aluminum gives superior strength and better anti-corrosive qualities.

Some very marked and valuable qualities have been discovered in the use of aluminum and zinc for various purposes.

A mixture of aluminum with zinc is made by the Delaware Metal Refinery, of Philadelphia, which has proved very useful in the galvanizing bath; adding one pound of the aluminized zinc alloy to each ton of spelter contained in the bath, and one pound of the alloy additional for each 1,000 pounds of new spelter put into the bath. The effects are to make the spelter more fluid, coating smoothly twenty per cent. more surface than ordinary spelter, with a surface that is brighter, more malleable and will double-seam much better than ordinary galvanized iron. The use of aluminized zinc for this purpose is patented by Jos. Richards, of Philadelphia.

The aluminized zinc has also been added to good advantage as an addition to ordinary brass mixtures; about one per cent. to the weight of the brass mixture of aluminized zinc being used, plunged with a pair of tongs under the surface of the metal, where it is stirred with a rod. The surface of the brass mixture is then skimmed, and after waiting about half a minute, until the bubbles of disengaged gas cease, poured as usual. The effects are to make sounder castings, increase the strength, and give a finer color to the metal, which will resist oxidation much longer than ordinary brass. Should the amount of iron in the brass mixture be high, as large an amount as two per cent. of aluminized zinc can be added to liquefy the iron. The use of aluminized zinc for brass alloys gives a heavier yield of metal than without its use; and the Delaware Metal Refinery people claim that the increased yield and sounder castings produced will much more than pay the slightly increased cost of the brass mixture by the addition of the aluminized zinc.

Aluminum has been successfully used to replace lithographic stone.

Powdered aluminum mixed with chlorate of potash is used to give a photographic flash-light, which gives much less smoke than the magnesium compounds used.

The Tacony Iron Metal Company, another well-known Philadelphia concern, has successfully produced an aluminum coating for iron, which undoubtedly will have considerable use in the future.

Samples of their work I take pleasure in showing you this evening.

To the inventors who shall produce good methods of nickel-, silver- and gold-plating aluminum so that it can take the place of german- and nickel-silver, a rich reward is in waiting.

I have endeavored in the latter portion of this lecture to indicate a few of the uses that have already been established, and the openings that seem most prominent to my own observation for the use of aluminum. Undoubtedly, there are many other fields yet waiting for the metal which will yield rich returns to the successful investigator; and I close this lecture by again reiterating the prophecy that the financially most successful solution of the aluminum problems of the future "will be in the ways of utilizing the metal in the arts, rather than in devising more economical methods of manufacture."

PHILADELPHIA AS A SEAPORT.*

By Capt. F. A. Mahan, Corps of Engineers, U.S.A.

[*Concluded from p. 202.*]

The little city of Newcastle-on-Tyne has not been backward in improving the stream which affords the means of carrying away its coals. In 1843, at some points the water was only two feet deep at low tide. The difference between low and high water was twelve and one-half feet. Even at high tide the river was so obstructed by bars, and the channel was so tortuous that vessels often needed two and three tides to reach the sea, only twelve miles away. For years the city has been at work dredging out the river, and from 1838 to December 31, 1889, the enormous quantity of 86,900,000 tons, nearly 60,000,000 cubic yards of material was removed. In addition to this great piers have been built out into the North Sea, so as to facilitate passage over the bar at the mouth of the river, and to make a harbor of refuge for vessels plying along the coast, and the Northumberland and Albert Edward docks were dug. These docks have a combined water area of seventy-nine acres. During the thirty-nine years, from January 1, 1851, to December 31, 1889, the sum of nearly $50,000,000 has been spent, and an income of nearly $28,000,000 has been received.

In the case of neither the Clyde nor the Tyne has any mention been made of the increase of prosperity of the cities of Glasgow and Newcastle. The industry most intimately associated with these cities in the American mind is their ship-building. The yards of the Clyde are celebrated, and most of the great transatlantic racers come from them. Hardly less so are the yards along the Tyne which in five years, 1880 to 1884, both included, turned out 597 ships of 1,435 tons average.

In the cases of the Clyde, the Tyne and the Manchester Canal, the work has all been done with the sanction, but without any pecuniary assistance from the general government. They are great commercial ventures which, in the case of the first two, have proved immensely profitable and the last is likely to be not less so.

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* A lecture delivered before the Franklin Institute.

Turning now to the city of Antwerp we find a new system wherein part of the work is done by the city and part by the general government. It is very difficult, if not impossible, for one not thoroughly familiar with this port to say just what has been done by each. Of one point we are sure: the general government built the magnificent quay wall on the right bank of the Scheldt, between the years 1877 and 1884, at a cost of about $8,000,000. Of another point we are sure: in twenty-five years, from 1859 to 1884, the city spent on the enlargement and equipment of its docks more than $15,000,000, or $600,000 a year. This may be called doing pretty well for a city which, in 1859, had a population of 108,500, and in 1884, 201,400. Its advantage is seen in this statement: From 1830 to 1840, the average daily tonnage entering the port was 440; from 1880 to 1885 it was 9,572, and at the present writing it is probably far beyond 10,000 tons per day.

It is useless to carry these accounts further. We everywhere find the same extensive works going on. It is only in our own country, the one of whose greatness we are constantly talking, that we find—nothing.

New York indeed has made a beginning, and so far as I am aware, it is the only one of our American cities which has undertaken the improvement of its water front in a systematic way. A plan for this work was drawn up and adopted several years ago, and since then the improvement has gone ahead, every year approaching a little nearer to completion. Whether it will ever catch up to the growth of the city is hard to say. As the method of carrying on this work is of our own country, a short account of the organization which has it in charge may be interesting.

All work along the river front is under the control of the Department of Docks, which has exclusive charge and control, subject in certain cases to the approval of the Commissioners of the Sinking Fund, of all wharf property including wharfs, piers, bulkheads and structures thereon and waters adjacent thereto, and all ships, basins, docks, water fronts, land under water and structures thereon, and the appurtenances, easements, uses, reversions and rights belonging thereto, and which are now owned or possessed by the city of New York, or to which it is or may become entitled. It has exclusive charge and control of all operations of construction or repair, of dredging and deepening around and between piers, and of leasing and protecting all wharf property. It has exclusive government and regulation of piers, wharves, bulkheads, slips, docks, basins, etc., with all structures thereon, water thereto adjacent and land under the water. But while it has authority, with the approval of the Commissioners of the Sinking Fund, to change the location and width of piers, it has no power to change the exterior lines of piers and bulkheads as established by law.

The Department of Docks is composed of three Commissioners, who are appointed by the Mayor and who serve six years at a salary of $3,000 a year. The Commissioners must be residents of the city, and ceasing to be residents they cease to be Commissioners. They may be removed from office by the Mayor, subject to the approval of the Governor of the State. In case of a vacancy arising before the expiration of the term of one of them, the successor is appointed only for the unexpired portion of the term.

Funds for carrying on the works are obtained through the issuance by the Comptroller of "dock bonds of the city of New York." These bonds bear interest at six per cent., and are redeemable from time to time, but not before thirty years. Not more than $3,000,000 may be issued in any one year, and none of the bonds may be sold below par. The money obtained from these bonds is deposited in the city treasury, and is paid out on requisition of the Department of Docks, countersigned by the Commissioners of the Sinking Fund. It is used for payment of all work done, for salaries, for the purchase of property, or the payment of damages awarded under appraisement. Property acquired by condemnation is obtained under the same rules and regulations as that for streets and public places.

Work may be done by contract, in which case twenty-five per cent. is retained on all partial payments, or by day's labor if so ordered by the affirmative votes of all the members of the Board.

Upon the completion of the wharves, piers, etc., and their being opened for use, the department regulates all charges for wharfage and dockage, which it may alter from time to time as necessity may require. Leases may be made to special parties or corporations for terms not exceeding ten years, and agreements may be made for renewals at advanced rates for fifty years. All leases, other than those made for districts appropriated by the department to special commercial interests, are to be made at auction to the highest bidder. Lessees may be required to make all needful repairs and keep the leased property in good condition under penalty of forfeiture and damages; or they may be required to keep in order, in general terms, what is above the water while the department does the same for what is below.

The department makes all rules and regulations for the care of property and affixes penalties for their violation, not to exceed $500 fine or thirty days' imprisonment, or both, judgments to be obtained, by suit in the name of the city. All rents, fines and penalties, and other money collected by the department, belong to the city and are paid into the sinking fund.

It makes an annual report, in which are given:

(1) The names, occupations and pay of all persons appointed and employed by the department.

(2) A statement of the action of the department for the past year, classified with reference to the various subjects and duties which have engaged the attention of the Board.

(3) A list of orders and rules and of the contracts made by the department, payments with the purposes and amounts thereof, and the leases drawn, together with the terms, rentals, names of lessees and description of the properties leased.

It may deepen the water near and adjoining any private wharf, pier, dock or bulkhead, or land within the city, in such places and at such times as it may deem necessary and proper.

It may remove any vessel, raft or float from any place where it may be moored or anchored, whenever such removal may be necessary for the convenient prosecution of work doing under the department.

It must furnish mooring places for the public baths upon requisition from the Department of Public Works.

It has to assign such slips or berths in slips and at piers as may be convenient and necessary for the Department of Street Cleaning.

Such, in brief, is the organization of the New York Department of Docks. Its executive officers are a Secretary and a Chief Engineer, the latter receiving a salary of $6,000 a year.

The necessity of having the approval of the Commissioners of the Sinking Fund in certain cases is most unfortunate, and it has, at times, greatly cramped the action of the Dock Department. In fact, the Commissioners of the Sinking Fund have it in their power to put a stop to work, by refusing to countersign the requisitions for funds of the Dock Department. One Board is bad enough, but two of them is well-nigh impossible, and that the operations of the New York department have been so successful is largely, if not wholly, due to the able engineers who have directed them.

Let us examine now the relation of the Port Wardens of Philadelphia to that port, and compare their duties and powers with those possessed by the Department of Docks of New York. So far as the purposes of this lecture are concerned we may say that they have no powers at all. They can acquire no property, they can direct no work, they can take no initiative. To be sure they can play a negative part—that is to say, if a person wish to construct a wharf or bulkhead the approval of the Wardens must be had, and they must be convinced that the applicant is the real riparian owner. For the purpose of improving the facilities of the port the Wardens have no powers, and the same is true of the Harbor Commissioners.

At the present time there is no way by which anything can be done in Philadelphia to meet the second, third and fifth conditions which should be fulfilled if this port is to take high rank.

Turning now to the fourth condition, the necessity of easy access to the interior, we find a state of affairs very difficult to overcome. In respect to inland communication Philadelphia is, without doubt, badly off. The topography of the State of Pennsylvania is such that the construction of a water connection between the eastern and western sections is well nigh an impossibility, except at a price which is prohibitory in the present apathy of the public mind toward waterways. As water will not run uphill, a canal cannot be carried over the mountains after the fashion of a railway. This makes the passage from one water-shed to another a difficult problem, and the more so if the slopes on each side of the crest be steep, which is the case in this State with those of the Susquehanna and Ohio. Still as improvements continue in canals, and lifts are constructed which raise boats carrying 300 to 400 tons through heights of fifty feet and more, we may hope to see interest in the subject revive. Who shall say that American genius cannot devise the means of raising a boat carrying 1,000 tons through a height of seventy-five or eighty feet? It will not be so daring a feat as the construction of a 550-span bridge for a railway, or that of the suspension bridge between New York and Brooklyn. These lifts are costly, to be sure, but they solve in the simplest way one great question of canals, the water supply of the summit level. They also save much time because a boat has only one lock to enter and leave for a difference of level equal to the reach of the lift, whereas with the ordinary system the operations must be repeated at each lock. The time of going up and down by a lift is very short. At Anderton, on the River Weaver, the time required to raise one boat and lower another fifty-two feet was about two minutes.

As interior communication cannot be had for the time being by water without leaving the boundaries of the State, we must turn our attention to the railway avenues of exit with which, as I have said before, the city is fairly well provided. Three important lines of railway centre here: the Pennsylvania, the Baltimore and Ohio and the Reading. The Lehigh Valley comes in and will probably make use of the Pennsylvania terminals. Of these four lines the Pennsylvania has the predominant influence and by reasons of its terminal facilities practically controls the railway freight business of the city.

The complaint is made that the Pennsylvania discriminates against the city in favor of New York and Baltimore. Why not? Is not discrimination at the very bottom of almost all business? What are card rates but a means whereby discriminations can be made in favor of one customer as against the other? To be sure discounts are largely governed by the size of the orders. Is the freight business of Philadelphia as great as that of New York? The railroad has also competition from both the adjoining cities, and makes for them rates to meet the competition. Wherein does it differ from the seller? Where the latter has a field to himself does he sell as cheap as when a competitor appears and offers better rates? A railway sells services as a manufacturer sells goods, each at the highest price to be had.

Again, the complaint is made that the railroads control legislation to too great an extent. But whose is the fault? The blame lies with us—the people. So long as we choose for office men who can be influenced by passes or other inducements offered by the railways, so long will they act in favor of these bodies unless some other body appears and offers a higher bid. If you wish unbiassed action you must choose men who cannot be biassed. If you wish independent action you must choose independent men. So long as the best men will neglect their duty to their city, their State or their country, by direct service or by direct votes, just so long will these duties be exercised by the inferior men, and the best men must suffer. Nature pardons no blunders. Whether they arise from accident, design or neglect, their consequence follows. The question of the railways is a question of business. So far as I can see they do as every one else does, but their action is further reaching, touches more people and is therefore more felt.

Some of you may ask, What bearing has this discussion of railway matters on the question of Philadelphia as a seaport? Simply this, that if a city cannot get goods from the interior to send away by sea, or cannot ship inland what comes by sea, of what use to create the port unless it be proposed to deal mainly with foreign ports? There is the whole matter. As I said before, a city is a transformer or a transhipper, or both. Under existing circumstances Philadelphia is not a great transhipper. She is a great transformer. Her true position is the same as that of Manchester, to collect materials from all parts of the world, to transform them, and then to distribute the finished product back to the world. If she cannot compete on equal terms with other places for the trade of the country, she can so compete for the trade of the world, because the ocean is free to all.

Now what should be done to make Philadelphia the port which, by her population and the capital embarked in her many enterprises, she might and ought to be? The answers are numerous and depend on the points of view and modes of thought of the writers. It may be said, however, that it is an exceedingly simple matter to evolve a plan. You may have heard the story of the way in which an Englishman, a Frenchman and a German would go to work if each were called on to contribute a chapter in natural history on the lion. The Englishman, it is said, would shoulder his rifle and start for Africa, and hunt the lion on his own ground while studying his habits. The Frenchman would stroll over to the zoölogical garden and there study the animal as he walked about or lay quiet in his cage. The German would shut himself up in his room, light his pipe, and evolve a lion out of his inner consciousness and a cloud of smoke.

Many of the persons who have ideas in matters of this sort work on the German's plan. They shut themselves up in their rooms or offices and proceed to elaborate a system which is in itself nearly perfection, but they take no account of the many failing cases which must present themselves. They lose sight of the condition of the water front, the way it is divided up among very many holders, some of it belonging to individuals living, some of it to estates;

some of it tied up with conditions in the original Penn Charter; some by conditions made by persons of recent date. Every plan proposed is met, too, by selfishness on the part of some one or other, who takes advantage of every chance to oppose what does not coincide with his pet scheme.

My own ideas on this subject, which I shall present to you, are probably as crude and open to as many objections as those of any who have presented their views.

The first step to be taken is to have it clearly understood that "man does not live by bread alone;" in other words, that a city cannot live by manufactures only. Of what use is it to convert tons of iron or wool or cords of wood into articles for the use of mankind, if these articles be kept locked up in warehouses? Who would gain by such an operation? Trade is an essential accompaniment—it might almost be called an essential element—of manufacture. The finished product must be removed and more raw material must be brought in to take the place of what has been worked up. The mind of this city has been devoted too exclusively to mere manufacturing; it has not sufficiently thought on the trading feature. Trade seeks the cheapest routes for shipments. These routes are by water, and shipments by water require a port. The manufacturers must be made to understand that a first-class port is as essential to their business as is first-class machinery. The cheaper the transportation the cheaper the raw materials here, and the finished article there. All else being equal is, of course, understood. So the first thing is to direct public sentiment to the necessity of having a fine port.

The second step is to have the means of legally overcoming the obstacles which now exist to carrying out any project. Here the Legislature of the State must step in and exercise its right of eminent domain or confer it on the city. The laws for acquiring property for public use are sufficiently strong to make this a simple matter. It will take time and doubtless much litigation, but the principles are simple. Even when they must be beaten in the long run, the selfishness and cupidity of people will lead them to oppose all improvements in every possible way and by every possible crook. Naturally there must be some body appointed to represent the State or the city as the case may be, and this body will be doubtless somewhat on the same plan as the Department of Docks of New York, but it should not be subject to the whims of some other body, which knows nothing of its matters and which may merely wish to exercise a little arbitrary authority to show its power, without regard to the injury done to the work. But the organization of such a body cannot be made in a day, and will require much care and thought in elaborating its composition and its duties.

After the body to carry on the work has been appointed, its first duty will be to prepare a plan for the improvement. This plan will probably consist of a bulkhead wall running along the side of the river, and piers built out perpendicular thereto. Circulating space must be had from pier to pier and from the piers to the city, so that teams and cars may move freely, and this involves the widening of Delaware Avenue.

In all the articles and interviews which I have read in the daily papers, on the subject of making Philadelphia a greater port than it is now, there is one idea constantly advanced which seems to me vicious to the last degree. Every one admits that there should be a broad street along the bulkhead so that there may be room for drays and teams, and also for railway circulation. One element of successful work is space. Where space is lacking a jam is going to exist from time to time. A jam means loss of time and temper. Loss of time is translated by loss of money, and loss of temper by useless wear of the physical and nervous systems. A broad street is absolutely necessary.

The one way mentioned for widening the street is that of placing the bulkhead line further out in the river. This idea, to my mind, is bad. Water is the life of a seaport, and without water it cannot exist. Space is needed for free circulation in the river as well as on shore, but space has never in this world been had by contraction or subtraction. Furthermore we must bear in mind that the tendency of ships is to greater size, and greater size will require more room for handling. This shows us that the experiment of trenching on the waterway may be dangerous and full of disadvantages. The widening of the street can be far better made on the side opposite the river. It would be to my mind a better solution to remove everything from the river to the west side of Front Street I know full well that this is going to raise a storm of opposition, and at once the cry of the great cost of such a proceedure will be heard.

Between 1881 and 1884, the city of Antwerp, in Belgium, having at that time a population of 195,000, did not hesitate to expropriate 630 different buildings. During a visit to that city in the spring of 1884, I saw some of the houses which were to be removed, and they were far better than anything which I have seen along the river front of Philadelphia, the sugar refineries excepted, and I was informed by the assistant engineer that they were fairly representative of what had gone before.

The difference between the foreign and American methods is well seen in this. Here cheapness in first cost generally rules in the beginning, with endless inconvenience later on; there the question is studied carefully, the best course is adopted and the work is carried forward consistently on that line. There is no reason why we should not adopt a foreign idea if it be a good one. All the wisdom of the world is not sheltered by the wings of the American Eagle. Other nations have done and are still doing work which we may study with profit.

Have a care that no mistake be made. The city can spread out into the country, it does not need the river, but your commerce needs all of the river which is to be had. Preserve the river and, if it be necessary to do so, tear down twice or three times 630 houses. The city can well afford the first cost, and the result you may be sure will justify the deed. Again, all this need not be paid for at once. As the buildings are taken one at a time, their appraised value can be paid, and coming a little at a time, the cost will not be felt.

And here let me call your attention to a future danger.

I learn that the Pennsylvania Railroad is already trying to mortgage the future, and obtain possession of Delaware Avenue so soon as it can and lay its tracks to the exclusion of all comers, the city included. Tracks on Delaware Avenue are an essential feature of any improvement, but they should belong to the city and be controlled and administered by the city, or by the body in which the care and management of the wharf system are invested by the Legislature. This service must be absolutely impartial.

In referring thus to the Pennsylvania, I am moved by no idea of hostility to that road. I merely wish to state emphatically that the management of the pier service should be absolutely impartial and should be kept out of the hands of any railroad company whatever.

The question of money will have to be carefully considered. But here comes in that which is to me a curious feature of the American character. In talking with some persons on this subject, the great cost of such an undertaking as the improvement of the front, the removal of buildings, equipment of quays and piers with proper machinery, has been mentioned as militating against it. It would undoubtedly be a tremendous thing to think of spending $20,000,000, for example, in a month or a year, and in considering the subject, they seem only to see the expenditure of that amount in one block to be made to-morrow or next day. The principle on which the work is done is the same as that on which a man buys his house from a building society. If you call on a man having a yearly wage of $1,200 to pay $2,000 cash down for a house, you scare him off, but if you give him a long period in which to make his payments, a little every month, in time he has his house without incurring any hardship. So, for the city to pay out (say) $20,000,000 in one year would be tremendous, but spread this over ten years and it reduces to $2,000,000 a year, or over twenty years, and it comes down to only $1,000,000. Then, too, the income from such works is apparently great. Witness the Clyde and Tyne improvements, where the income has been from fifty to sixty per cent. on the outlay. The method of raising the funds I shall not discuss, as that is properly the work of trained financiers.

After the plan of the work has been adopted and the means of raising the necessary funds provided, the execution must be begun and carried forward along the approved plan. To be sure there will come up slight changes in details from time to time, but there must be no radical departure from what has been approved.

Changes of this sort are provided for in the New York laws, but I think that the approval of the Commissioners of the Sinking Fund is bad. If approval must be had it would better be from an advisory commission of citizens interested in the commerce of the port and in the navigation of the river, as they would appreciate the wisdom of a change of detail far better than could a commission composed probably of politicians.

In the execution of this or any similar piece of public work, it is absolutely necessary that the charge of it be given to a man of education and broad experience. The Archduke Charles of Austria, one of the great writers on the art of war, says: "A man can become a great captain only by passionate and unremitting study and long experience. What one man has seen by himself, does not suffice, for what life of man is fruitful enough in events to give universal experience? And who is the man that can have the opportunity of *first* practising the difficult art of the General *before* holding that important office? It is by adding to one's own stores of knowledge the information of others, by weighing the conclusions of one's predecessors and by taking, as a term of comparison, the military exploits and the events great with results which the history of war gives us, that one can become skilful in war." By changing very few words what is here said applies with equal force to the engineer. He must have knowledge, he must have experience. What others have done he must have made his own.

One great trouble of our American people has been, until within very few years, the desire for the so-called practical man; in other words, for the man whose knowledge is bounded by the extent of his own work. Educated in many cases by men as ignorant as himself, he thinks that the sum of human wisdom in his particular line is in his own possession. Wherein the deeds of others differ from his modes, therein are they wrong. By such men, alas! is almost every profession in this country overrun, and this is true of engineering in probably a greater degree than any other. Men who do not even know how to set up a transit or a level properly, call themselves engineers and hold themselves ready to deliver an opinion, at five minutes' notice, on subjects to which great minds have given years of toil. From this condition we are gradually emerging. The many excellent special schools throughout the country, the various engineering reviews and periodicals, show that the demand for educated men is on the increase and that the people begin to appreciate that only good tools do good work.

After the engineer has completed his studies and prepared his plans for the execution of the work, it may be well as an act of prudence to submit them to a commission of experts, in order to have the assurance that nothing has been overlooked. As a rule, I do not believe in commissions. It stands to reason that no body of men can gain, in a few hours or days, the knowledge which has been acquired by the one man who has devoted months and even years to his special work. A commission generally ends in one of two ways: (1) The individual work and force of one member may dominate the whole body, in which case the report is that of one man; or (2) if all be men of a certain degree of force, or one or two of them of a certain degree of obstinacy, the report is a compromise and is of small value. No two men ever looked at the same picture with exactly the same light at the same time. One point seems essential to one man; another to the second, and so on.

Of one thing those who have the work in charge may be sure. No matter what plan may be adopted there will be plenty of condemnation and plenty of suggestions. The condemnation will come mainly from selfishness, and the suggestions from ignorance. It is impossible to satisfy every one. Our friends of the press frequently do much unintentional damage to matters of this sort by publish ing as valuable the opinions of persons who have not the knowledge necessary to give an intelligent opinion. For example, suppose the case of a reporter asking a lawyer or a merchant his opinion, of some special engineering feature of the plan which may be adopted for the improvement of the harbor facilities. What would their opinion be worth? Just about as much as that of an engineer on some technical point of bank management. The lawyer and the merchant, assuming them to be intelligent men, are of the class to consider the business bearings of such a scheme. They throw valuable light while the question of to do or not to do is under discussion, but that stage once reached their function ceases and the matter passes into the hands of the engineer, because the doing of the work involves technical questions which the technical expert alone understands. Just as when it is a question of a suit in court; the laity may say whether or not the suit be advisable, but once in court it must be left in the hands of the lawyer, the expert.

Another class of men from whom trouble is to be expected is a certain sort of scientific men who are students only, men who have had charge of no work, who have the theory of their profession at hand, but who, for lack of practical experience or disposition, cannot adapt themselves to circumstances. Principles in any science are few; in their application is difficulty. The student generally knows what is best, but he lacks resource in makeshifts when the best is not at hand. Men of this sort are invaluable in their way, which is to take work done and dissect it, point out wherein lies departure from principles and where principles have not been well applied. But the acceptance of their suggestions must be greatly governed by circumstances. Every science owes a large debt to the many earnest men of this stamp for whom one can have no other feeling than that of respect, even if he cannot always uphold their judgment.

The method of organizing and doing a work of so great magnitude as the improvement of the water front of Philadelphia is one which needs careful thought. One obstacle, in fact it would be better to say two obstacles, stand in the way of carrying on public improvements successfully and economically. The first is that most false idea that every piece of public work, whether of the general government, of the State or of the city, must be run to the advantage of the party in power. If the administration be Democratic the work is to be used for Democratic needs, or if Republican no Democrats need apply. Look at every sort of government in the country, and what do you see? Every office is for the reward of party service so far as the party in power for the time being can carry out the idea. But pray what has protection or free trade, or the passage or non-passage of a Federal election bill to do with laying out a proper line for a bulkhead, or for putting a stone truly and solidly in a wall? For the first are needed men of ability to grasp the situation, and for the second men of experience in spreading a bed of mortar and setting the stone thereon. Now will any one say, and so saying, does he really believe that because a Republican administration happens to be in office in Washington, a proper selection of the bulkhead line or the true setting of a stone can only be had by means of a high protective tariff, or that because the administration is Democratic the same operations can only be performed under the influence of a reduction in the tariff? Naturally, the idea is absurd.

The second obstacle is that men of influence in the community, of broad views, of successful administration of large business affairs, will not take part in a work of this sort.

Why this is so I do not understand. In times of war or of other great public commotion these same men stand ready to drop everything to go forth to battle, and even to die for the cause which they have at heart. In times of peace no inducement is sufficient to make them act for the public good, if it involve any sacrifice of time or money, unless indeed the loss be made up by some other consideration.

So long as great matters like building quays and piers are to be left to politicians, the people do not care to have their money spent for so-called public improvements. They feel that what is done represents but a small part of the total outlay.

The American is patient and long suffering; he is also very intelligent and wide-awake. After beginning a piece of work which he is determined to finish, he may allow double or even treble prices to be paid once, but when he finds how money has been squandered on one piece of work, he does not care to give an opportunity of the same sort again. If it were suggested that a great improvement like that of the water front of Philadelphia should be undertaken by the city government, I should not be surprised to see the whole population in arms against the proposal. Why? Seek the answer in the City Hall.

Whoever may be the men charged with carrying out this great work, they may be sure that if they seek honestly to do their duty as it should be done, their place will be no sinecure. They will be roundly abused by every man who has an axe to grind; they will be accused of every thought except the one of single-minded acting in the interest of the people; charges will be made against the honesty of their administration; "cranks" of every kind will haunt them, and selfishness and greed will pursue them in all sorts of shapes at every turn. Their days will be a burden, and their nights will be without rest. But through it all will shine a bright guiding star, the thought that the result of their labors will abundantly justify their struggles. Rome was not built in a day, and no great work ever came from a small idea. To make the port what it should be is the work of years, and to be worthy of the city it must be conceived on a grand scale.

A COMPUTATION OF JOULE'S EQUIVALENT.

By R. H. Thurston.

Some years ago, the late Dr. Pliny E. Chase, then of Haverford College, published in the *Journal of the Franklin Institute* a series of articles of singular interest, and of curious result, often in which he traced what he called certain harmonies of nature, exhibiting some strangely related or oddly coincident physical laws and constants, and in which he deduced a number of remarkable conclusions. He subsequently published a short paper, reprinted in the *Philosophical Magazine*, in which he showed some reason for anticipating that it might ultimately prove that the value of γ, the ratio of specific heats of gases, is simply the numerical quantity

$$1 + \frac{4}{\pi^2} = 1\cdot405285$$

(*Phil. Mag.*, 1885, p. 520.)

It occurred to the writer to compute the value of J, the mechanical equivalent of heat, from this assumed value of γ. Taking the best values of constants determined by Regnault, referring all quantities to the air thermometer, and taking air as the gas to which the constants so selected should appertain.

From the well-known equations deduced by both Rankine and Clausius, we have the equality,

$$C_p - C_v = R = \frac{p_0\, v_0}{T_0}$$

or the difference between the two specific heats is constant, a fact first pointed out by Carnot, and later proved by the modern methods of thermodynamics by the founders of that science.

Since we take

$$\frac{C_p}{C_v} = \gamma$$

we have

$$C_p = J\,c_p = \frac{\gamma}{\gamma - 1}\,R;\ J = \frac{\gamma}{\gamma - 1}\cdot\frac{R}{C_p}$$

and taking as Regnault's most probable values of C and of R, in British measure, 53·37 and 0·2375, we have

$$J = \frac{1{\cdot}405285}{{\cdot}405285}\cdot\frac{53{\cdot}37}{0{\cdot}2375} = 778{\cdot}12$$

in foot-pounds, or 427 kilogrammetres per calorie. This corresponds to about 775 on the mercurial thermometer, falls within about one-eighth of one per cent. of the value assigned to J, by the British Association Committee of 1876, and is somewhat lower than the figures obtained at the temperature of maximum density of water by Rowland in 1880. This determination would seem to lend some color of probability to the conjecture—for it seems to have been little more—of Dr. Chase. In further, and perhaps more satisfactory, confirmation of this, as at least a closely approximate value, as have the work of Dr. Röntgen, who, in 1872, obtained $\gamma = 1{\cdot}4053$, as a mean of ten best observations. (*Pogg. Ann.*, 1873, s. 580.) The probably most uncertain datum involved in this computation is the value of R; but it is probable that all these figures are very accurate and the computed value of J must be correspondingly so. Further examination of the value of R, which involves the location of the absolute zero, is desirable, however.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, March 15, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1892.

Dr. W. H. WAHL, President, in the chair.

Dr Wahl called attention to a number of bills for subscriptions to journals, the contraction of which had already been authorized. On motion, the Treasurer was instructed to pay them.

Dr. S. C. Hooker read a very interesting paper on derivatives of lapachic acid. Dr. Hooker included in his paper a *résumé* of some of the more important results obtained by him during the past two years and also contrasted the views entertained by E. Paterno and himself. The paper was received with marked attention and interest by the members present. Specimens of the substances discussed were exhibited. The complete publication of these results will be deferred by the author for some time.

The section then adjourned. WM. C. DAY, *Secretary*.

NOTES ON IRON IN BONE-BLACK.

BY DR. BRUNO TERNE.

The freshly-prepared bone-black of the market yields on an average from 0·1 to 0·3 per cent. of iron in the form of metallic iron, originating principally from iron mixed with the bones gathered up by the junk dealers, another portion coming from the wear and tear of the bone crushers and mills, and a very little from the iron vessels used in burning the bones.

Having been in charge for the last fifteen years of one of the largest plants for manufacturing bone-black, I had never experienced any trouble with our product, on account of the iron, until several months ago, when one of our patrons complained of an excess of iron in our black, which, according to his investigation, had run up in one instance to one-half of one per cent.

This complaint was coupled with the assertion that an increase of 0·25 per cent. of iron above the average would materially impair the process of refining sugar.

This charge coming from a source commanding serious consideration, caused us to look into this matter thoroughly, but an examination of the literature of sugar refining, covering a period commencing with 1872 (*Wagner's Jahresberichte*) up to date, failed to disclose a single case in corroboration of the above-cited assertion.

The more I thought over the matter the more I became convinced that the complaint made against our black, that it impaired the work of refining sugar liquors, was merely a convenient pretext to shield some irregularities in the process of refining, which otherwise would have to be shouldered at home. We all know that organic acids will dissolve iron, but in refining sugars the liquors should be free from acids or at least nearly made free by previous neutralization; the traces of free organic acids must certainly all be absorbed by the six to seven per cent. of carbonate of lime contained in fresh bone-black. The fact that in discarded black the yield of carbonate of lime is reduced to three or four per cent., and the yield of iron considerably raised, demonstrates clearly that fresh black operates to free sugar liquors from iron as well as other impurities.

In order to ascertain what effect a solution acidified with organic acid would have on the iron in bone-black, I prepared two solutions of citric acid containing respectively 0·1 per cent. and 0·25 per cent. of free acid.

The acidity of these solutions is so great that no sugar liquor entering filters will ever approach it in acidity.

I selected a black which had given by analysis a yield of 0·5 per cent. of iron, and made the following experiments:

							Per Cent.
(*a*)	5 grammes of black with 500 cc. citric acid solution of					. .	0·1
(*b*)	10	"	"	"	"	" . .	0·1
(*c*)	5	"	"	"	"	" . .	0·25
(*d*)	10	"	"	"	"	" . .	0·25

I exposed the four flasks on the top of a steam heater for twenty-four hours to a temperature of 150° to 160° F., after which I tested the still acid solution for iron with potassium sulphocyanide and potassium ferridcyanide, but no trace of iron could be found in the solution.

Not satisfied with this I kept the flask for eighteen hours on a steam-bath at a temperature of 200° to 212° F.; the results of the two experiments were absolutely the same.

To operate on a sample of black large enough to place the result of the experiment beyond any doubt, I took 250 grammes of the same black yielding one-half per cent. of iron and treated the same with two litres of citric acid solution containing 0·25 per cent. free citric acid, for twenty-four hours on the steam-bath at nearly 212° F.

At the end of this time the acidity of the solution had completely disappeared and the absolutely neutral solution showed not a trace of iron with the most sensitive reagents (potassium sulphocyanide and potassium ferridcyanide).

I went still a step further and prepared a solution of iron in citric acid, 200 cc. of which contained 1·01 grammes of iron. I took 100 cc. and diluted to 500 cc.; I mixed the dark-yellow solution in a flask with 500 grammes of fresh regular sugar-house black, boiled up for thirty minutes, filtered and obtained a perfectly limpid solution which contained not a trace of iron.

This experiment proved to my own satisfaction that an accidental excess of 0·25 per cent. of iron in fresh black could not be charged with creating irregularities in the process of refining sugar liquors. But not being an expert in sugar refining I submitted this problem with the above results of my own researches to my friend, Dr. Arno Behr, now Secretary and Treasurer of the Chicago Sugar Refining Company, an acknowledged expert in this branch of chemical industry at home and abroad. I submit herewith an abstract of his letter:

CHICAGO, January 4, 1892.

MY DEAR DR. TERNE: * * * "Iron is a very objectionable substance to have in filtered sugar solutions, because the refined soft sugars which are produced from such solutions take on a more or less gray appearance, which reduces their value considerably compared with others, which are free from iron and of a bright yellow color.

"Colonial raw sugars contain sometimes a considerable amount of iron, and in the absence of good chemical methods for the removal of this iron from the unfiltered liquor, the refiner relies on the bone-black to absorb it.

"In some refineries the sugar solutions enter the black practically neutral, in others they are left a little acid, but this is of no consequence, for you have found yourself that new black will absorb the iron even from a strongly acid solution. Even old working bone-black contains enough carbonate of lime (three to four per cent.) to neutralize any considerable excess of acid. There is, however, a considerable difference in the behavior of new and old black. Say you want to filter 100 pounds of dry sugar over 100 pounds of bone-black. Say this sugar contains two to three-hundredths of one per cent. of Fe_2O_3. The solution will come from the new black absolutely free from iron, while from the old black half of it perhaps will be free, and the other half will contain it in increasing quantities.

"This will happen with properly neutralized liquor and without any fermentation having occurred. Even if the sugar solution enters the black free from iron, towards the end it will come from the old black containing iron.

"It works this way without any attempt having been made to wash the liquor out of the black. As soon as that is done matters become worse. Even from very good black the diluted sugar solution carries away a certain amount of iron.

"Now in working it is found that the amount of iron increases in the black with its age, and that in the same proportion the amount of iron increases in the liquor. There is no way of removing the iron once absorbed by the black.

"There are three sources of iron in the black:

(1) "The iron originally contained in the black.

(2) "The iron in the raw sugar.

(3) "The iron taken up by the liquors and the bone-black in the sugar refining.

"The liquor has very little chance to dissolve iron, but the bone-black gets more or less of it by its passages through the kilns. The iron in the raw sugar the refiner has to take and make the best of, but in the case of the iron in the new black he will naturally fall back on the bone-black manufacturer and I do not blame him.

"It is reasonable to expect that a black with 0·1 per cent. Fe will furnish iron-free liquors for a longer time than one with 0·3 per cent. Fe. Most of the iron in new bone-black is in the metallic state and can be removed by running the crushed black over a magnetic separator.

"With best regards, Yours very truly,

"ARNO BEHR."

Certainly every one will agree with my friend, Dr. Behr, that 0·1 per cent. impurity of anything is to be preferred to 0·3 per cent.; the self-interest of the manufacturer will command the adoption of such means as to keep the percentage of iron as low as possible.

In the interest of manufacturers of bone-black everywhere, I thought it, however, of sufficient importance to refute the theory that an accidental excess of a fraction of a per cent. over the acknowledged unavoidable proportion of iron in new black, could be held accountable for any disturbance in the process of sugar refining, and to have my protest recorded with the section against such a claim.

This point has been fairly covered by my own experiments, and is clearly corroborated by the opinion of one of the most competent sugar chemists of this country.

Regarding the chemical methods of iron determination which are far too laborious to perform every day, I have been trying to find a method which could be carried on with sufficient accuracy without requiring previous chemical training.

I found that a boy, with the help of a magnet, could, by exercising the necessary care, make a determination, sufficiently accurate for the daily control of a bone-black mill.

Take 100 grammes of the black and spread it in a thin layer over a sheet of white paper, then plow through it with a good magnet (I am using a six-inch horseshoe) and it will be found that most of the iron will be picked up at the first few passes.

After repeating the passes of the magnet in every direction, carefully observing that no part of the mass is missed, in a very few minutes all the iron will have been gathered on the watch glass ready for weighing. The results thus obtained come sufficiently close to those obtained by chemical test to serve as a control upon the process of manufacture, as the following examples will show:

The following tests have all been made within the last four months:

	By Chemical Analysis. Per Cent. Iron.	*By Magnetic Test. Per Cent. Iron.*
October, 1891,	0·360	0·410
1891,	0·160	0·219
December, 1891,	0·387	0·501
January, 1892,	0·100	0·130
1892,	0·169	0·213
1892,	0·080	0·107
1892,	0·199	0·224

While the magnetic test is invariably too high, it is sufficiently close to control the work of the black mills. The adherence of particles of carbon to the iron fully explains this result.

Regarding the chemical determination of iron, I consider a previous incineration of the black necessary, because there is a possibility that traces of organic matter left in the fresh black may be mistaken for iron by the reduction of the potassium permanganate.

ON THE USE OF OIL IN AMMONIA GAS COMPRESSORS AND ITS INFLUENCE ON THE EFFICIENCY OF THE COMPRESSORS.*

By DR. HANS VON STROMBECK.

At the suggestion of Mr. Louis Block, Chief Engineer of the De La Vergne Refrigerating Machine Company, of New York, I conducted a series of experiments in the year 1887 for the purpose of determining the influence, which the injection of the oil into the compressor of this company's machine has on the efficiency of the gas pump. There had been considerable controversy on this point, and it was with the view of settling finally this question of dispute that a sufficient number of carefully conducted tests under varying conditions of pressure and temperature were made. The results of my investigations are laid down in the following treatise, accompanied by a number of tables and curves, which will fully illustrate the matter.

In the old form of the De La Vergne single-acting compressor, the cold oil was drawn by a plunger-pump from a reservoir or tank (the low-pressure or vacuum tank), which communicated by means of a pipe with the suction side of the machine, thus maintaining in the tank a constant pressure equal to that under which the liquid ammonia evaporated in the cooling-coils of the system. The oil-pump on its down-stroke discharged the oil thus drawn from the low-pressure tank into the gas-compressor, while the piston of the latter was likewise on its down-stroke, *i. e.*, after the compressor had taken its full complement of gas. On the up-stroke of the compressor-piston the gas and oil were discharged through the large valve of the dome, the oil following the gas after the latter had passed out of the compressor, both being heated in consequence of the compression of the gas. Under the increased pressure of compression a certain amount of ammonia gas was absorbed by the oil present over the piston. The oil thus charged with gas and after leaving the dome of the compressor was dropped into a separator, the so-called pressure tank, where it collected at the bottom. From here it passed through an oil-cooling coil and was collected at the bottom of the before-mentioned low-pressure oil tank, and being there exposed again to the suction-pressure of the machine, lost the identical amount of gas which it had previously absorbed during the compression period in the compressor. This amount of gas passed off into the suction-pipe of the gas-pump without doing any efficient cooling work, and therefore represented a certain loss in the efficiency of the compressor, which to ascertain was the object of my experiments.

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* **From the Laboratory of the De La Vergne Refrigerating Machine Co.**

To solve the question it was necessary to first make a series of tests as to the amount of ammonia, which the oil (or liquid base as it has been termed by the De La Vergne Company) could hold in solution under different pressures and temperatures. Though it is generally believed that the quantity of gas absorbed by a liquid (the temperature remaining the same) is proportional to the absolute prevailing pressure, it will be seen at a later place of this paper, that this law does not hold good as strictly as is generally believed. Therefore, it is always necessary to ascertain by tests, whether or not a gas follows this law. Thus the amount of ammonia which the liquid base could hold in solution under different pressures and temperatures being known, and the pressure and temperature of the oil in the low-pressure oil tank as well as in the high-pressure oil tank being likewise known, the amount of ammonia contained in one charge of oil can be found by calculation, first when this oil is injected into the compressor, and second when it leaves the compressor. The difference between the two quantities of ammonia represents the loss during each stroke of the compressor, and the number of cubic inches occupied by this ammonia under suction-pressure, and the cubical contents of the compressor being known, the ratio of the two volumes will represent the percentage of loss.

To illustrate this by an example, let us assume a single-acting compressor of 12 inches diameter and 24 inches stroke, the contents of which are equal to 2,714 cubic inches. It is the practice of the De La Vergne Company to inject into this compressor thirty-five cubic inches of liquid base, at each down-stroke.

Now let us assume:

A condensing pressure of	146·7	pounds	absolute,	temperature	150° F.
A back pressure of	44	"	"	"	70° F.

According to Table V:

								Volumes.
1 volume	of liquid base	absorbs at	146·7 lbs.	absolute	pressure	and	150°,	12·430
1	"	"	44 "	"	"	"	70°,	6·599

both volumes reduced to normal pressure (14·67 pounds) and 32° F.

One volume of oil therefore loses, if reduced from 146·7 pounds and 150° to forty-four pounds and 70°: 12·430 — 6·599 = 5·831 volumes of ammonia at normal pressure and 32°; and if subjected to a pressure of forty-four pounds and a temperature of 70° these 5·831 volumes will occupy only 2·09 volumes. Consequently the ammonia which is allowed to escape out of the thirty-five cubic inches of oil injected, occupies 73·15 cubic inches under pressure and temperature of the suction-side of the compressor; and the contents of the latter being 2,714 cubic inches, 2·69 per cent. is the loss in efficiency of this compressor.

In the new system of oil-circulation in the De La Vergne compressor even this small item of loss is entirely obviated, because the oil is now injected under pressure into the compressor after the same has taken in its full supply of gas.

The oil or liquid base used in the De La Vergne machine is a mineral oil, because all vegetable and animal oils saponify in connection with ammonia.

In distilling this oil in fractions the result is as follows:

		Per Cent
Volatile bodies, distilling over at	464° to 500° F.	0·5
	500° to 536° F.	0·7
	536° to 572° F.	0·4
	above 572° F.	92·2
Non-volatile residue,		6·2
		100·0

The flashing point is at 380°, the congealing point at 6°, the specific heat is 0·4618.

TABLE I.—SHOWING THE SPECIFIC GRAVITIES OF LIQUID BASE AT TEMPERATURES FROM 50° TO 280° F.

Temperature.	Spec. Grav.	Temperature.	Spec. Grav.	Temperature.	Spec. Grav.
50	0·9115	130	0·8847	210	0·8575
60	0·9069	140	0·8812	220	0·8538
70	0·9057	150	0·8778	230	0·8501
80	0·9037	160	0·8744	240	0·8464
90	0·8991	170	0·8711	250	0·8427
100	0·8952	180	0·8674	260	0·8390
110	0·8915	190	0·8648	270	0·8353
120	0·8881	200	0·8612	280	0·8316

While perusing the literature on ammonia, I found some data which I think are not as generally known as they ought to be and which I, therefore, give in the following. Determination of the quantities of ammonia, which are absorbed by water at atmospheric pressure, have been made by Sims, Bunsen, Roscoe and Schorlemer (cf. *Ann. d. Chem. and Pharm.* 117, 118). I give the figures obtained by them in Table II, a graphic representation in *Fig. 2*. It will be seen that the figures obtained by these scientists differ more or less from one another, and the rather surprising fact will appear that even at 212° ninety-seven volumes of ammonia gas are still absorbed by water.

Determinations of the quantities of ammonia which are absorbed by water at different pressures, have been made by Sims (*ibid.*). I give the figures obtained by him in Table III. In *Fig. 3*, I give a graphic representation, the full lines showing how the absorption of ammonia by water in reality takes place according to Sims' tests; the dotted lines showing how the absorption ought to take place according to the above-mentioned law, if we take the figures of Sims, Bunsen, Roscoe and Schorlemer, respectively, as the true figures of the quantities of ammonia absorbed by water at 32°, 68°, 104° and 212°, respectively, and atmospheric pressure. It will be seen that the two lines only coincide at 212°, at the lower temperatures the amount of ammonia absorbed being more or less smaller than it ought to be.

TABLE II.—SHOWING THE ABSORPTION OF AMMONIA BY WATER AT DIFFERENT TEMPERATURES AND ATMOSPHERIC PRESSURE, ACCORDING TO DIFFERENT AUTHORS.

One Volume of Water absorbs the Following Quantities of Ammonia :

	Sims.		Bunsen.		Roscoe & Dittmar.			Sims.		Bunsen.		Roscoe & Dittmar.	
° F.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.	° F.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.
32·0	0·899	1,180	0·799	1,050	0·875	1,150	125·6	0·274	359	—	—	0·214	281
35·6	0·853	1,120	0·756	993	0·833	1,094	129·2	0·265	348	—	—	0·200	262
39·2	0·809	1,062	0·717	942	0·792	1,040	132·8	0·256	336	—	—	0·185	239
42·8	0·765	1,005	0·681	895	0·751	986	136·4	0·247	324				
46·4	0·724	951	0·649	852	0·713	936	140·0	0·238	312				
50·0	0·684	898	0·618	813	0·679	892	143·6	0·229	301				
53·6	0·646	848	0·592	777	0·645	847	147·2	0·220	289				
57·2	0·611	802	0·566	743	0·612	803	150·8	0·211	277				
60·8	0·578	759	0·542	712	0·582	764	154·4	0·202	265				
64·4	0·546	717	0·519	682	0·554	728	158·0	0·194	254				
68·0	0·518	683	0·498	654	0·526	691	161·6	0·186	244				
71·6	0·490	643	—	—	0·499	655	165·2	0·178	234				
75·2	0·467	613	—	—	0·474	622	168·8	0·170	223				
78·8	0·446	585	—	—	0·449	589	172·4	0·162	212				
82·4	0·426	559	—	—	0·426	559	176·0	0·154	202				
86·0	0·408	536	—	—	0·403	529	179·6	0·146	192				
89·2	0·393	516	—	—	0·382	502	183·2	0·138	181				
93·2	0·378	496	—	—	0·362	475	186·8	0·130	170				
96·8	0·363	478	—	—	0·343	450	190·4	0·122	160				
100·4	0·350	459	—	—	0·324	425	194·0	0·114	149				
104·0	0·338	444	—	—	0·307	403	197·6	0·106	139				
107·6	0·326	428	—	—	0·290	381	201·2	0·098	128				
111·2	0·315	414	—	—	0·275	361	204·8	0·090	118				
114·8	0·304	399	—	—	0·259	340	208·4	0·[illegible]	1[illegible]7				
118·4	0·294	386	—	—	0·244	321	212·0	0·074	97				
122·0	0·284	373	—	—	0·229	301							

In Table IV, I give the figures showing the quantities of ammonia absorbed by liquid base at temperatures from

32° to 300° and atmospheric pressure; *Fig. 4* shows the graphic representation of the same. In Table V, I give the figures, and in *Fig. 5*, the graphic representation, according to which the absorption of ammonia by liquid base takes place at temperatures of 32°, 70° and 150°, and absolute pressures from one to four atmospheres, the full lines showing the amount of ammonia in reality absorbed, the dotted lines showing the amount which ought to be absorbed. It will be seen that, contrary to the absorption of ammonia by water, the absorption of ammonia by liquid base is

TABLE III.—SHOWING THE ABSORPTION OF AMMONIA BY WATER AT DIFFERENT TEMPERATURES AND PRESSURES, ACCORDING TO SIMS.

One Volume of Water absorbs the Following Quantities of Ammonia:

Absolute Pressure in Pounds per Square Inch.	32° F.		68° F.		104° F.		212° F.	
	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.	Grammes.	Volumes.
14·67	0·899	1,180	0·518	683	0·338	443	0·074	97
15·44	0·937	1,231	0·535	703	0·349	458	0·078	102
16·41	0·980	1,287	0·556	730	0·363	476	0·083	109
17·37	1·029	1,351	0·574	754	0·378	496	0·088	115
18·34	1·077	1,414	0·594	781	0·391	513	0·092	120
19·30	1·126	1,478	0·613	805	0.404	531	0·096	126
20·27	1·177	1,546	0·632	830	0·414	543	0·101	132
21·23	1·230	1,615	0·651	855	0·425	558	0·106	139
22·19	1·283	1,685	0·669	878	0·434	570	0·110	140
23·16	1·336	1,754	0·685	894	0·445	584	0·115	151
24·13	1·388	1,823	0·704	924	0·454	596	0·120	157
25·09	1·442	1,894	0·722	948	0·463	609	0·125	164
26·06	1·496	1,965	0·741	973	0·472	619	0.130	170
27·02	1·549	2,034	0·761	999	0·479	629	0·135	177
27·99	1·603	2,105	0·780	1,023	0·486	638	—	—
28·95	1·656	2,175	0·801	1,052	0·493	647	—	—
30·88	1·758	2,309	0·842	1,106	0·511	671	—	—
32·81	1·861	2,444	0·881	1,157	0·530	696	—	—
34·74	1·966	2,582	0·919	1,207	0·547	718	—	—
36·67	2·070	2,718	0·955	1,254	0·565	742	—	—
38·60	—	—	0·992	1,302	0·579	764	—	—
40·53	—	—	—	—	0·594	780	—	—

according to the above-mentioned law, the differences existing between the two lines of 70° and 150° being due to error of observation. At 32° the absorption seemingly does not follow at all the law for the absorption of gases, the full line diverging upwards of about two and one-quarter atmospheres more and more from the dotted line. But this is only due to the fact that the ammonia comes nearer and nearer the point where it liquefies (the liquefying point of ammonia at 32° taking place at an absolute pressure of 4·215 atmospheres or 61·834 pounds), and the amount of any gas absorbed by a liquid always exceeds the amount which ought to be absorbed, as soon as the temperature of the gas comes near its liquefying point.

TABLE IV.—SHOWING THE ABSORPTION OF AMMONIA BY LIQUID BASE AT DIFFERENT TEMPERATURES AND ATMOSPHERIC PRESSURE.

Temperature in ° F.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.	Temperature in ° F.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.
	volumes.		*volumes.*
32	3·139	150	1·243
40	2·880	160	1·117
50	2·592	170	1·012
60	2·383	190	0·898
70	2·197	210	0·873
80	2·091	232	0·751
90	1·950	250	0·700
100	1·824	260	0·680
110	1·714	270	0·661
120	1·588	283	0·638
130	1·465	300	0·611
140	1·308		

The tests were made in the following manner:

Flask *A B C* (see *Fig. 1*) that is to be filled with liquid base is made of strong glass. It contains up to the beginning of its neck 555 ccm., the neck itself which is divided into cubic centimetres, contains 45 ccm., the whole contents of the flask thus being 600 ccm. It is filled with liquid base by means of a siphon to such an extent that afterwards, if heated up to the temperature at which the test is to take place, the liquid base reaches to the lower part of the graduated neck. Flask *A B C* is put on a support in the covered sheet-iron tank *D E F G*, which is filled with linseed-oil or water and can be heated up by means of the burners *H H* to any desired temperature, controlled by the thermometer *I* and kept uniform in all parts by means of the agitator *K*. The pipe *a b c* is capillary, the diameter of the pipes *d e f* and *e g* four mm. inside. Cocks *v* and *u* are common stop-cocks, cock *g* the plug of which has a wedge-shaped perforation; allows to regulate the quantity of ammonia escaping out of the flask *A B C* in the minutest manner. From *g* the escaping

TABLE V.—SHOWING THE ABSORPTION OF AMMONIA BY LIQUID BASE AT DIFFERENT TEMPERATURES AND PRESSURES.

Absolute Pressure Expressed in Pounds per Square Inch.	1 Vol. of Liquid Base absorbs Volumes of Ammonia, Calculated at 32° and Normal Pressure.					
	at 32° F.		at 70° F.		at 150° F.	
	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.	Volumes of Ammonia in Reality Absorbed.	Volumes which ought to be Absorbed.
14·67	3·139	—	2·197	—	1·243	—
18·34	3·862	3·924	2·862	2·746	1·477	1·554
22·00	4·914	4·708	3·399	3·295	1·811	1 864
25·67	5·677	5·493	3·946	3·845	2·053	2·175
29·34	6·333	6·278	4·442	4·394	2·387	2·486
33·01	7·354	7·063	5·041	4·943	2·671	2·797
36·67	8·039	7·847	5·657	5·492	2·959	3·107
40·34	8·933	8·632	6·219	6·042	3·247	3·418
44·01	10·046	9.417	6·599	6·591	3·556	3·729
47·68	10·990	10·201	7·344	7·140	3·841	4·039
51·34	12·338	10·986	7·724	7·692	4·169	4·350
55·01	13·427	11·771	8·352	8·239	4·467	4·661
58·68	15·655	12·566	8·529	8·788	4·692	4·972
146·70		calculated.				12·430

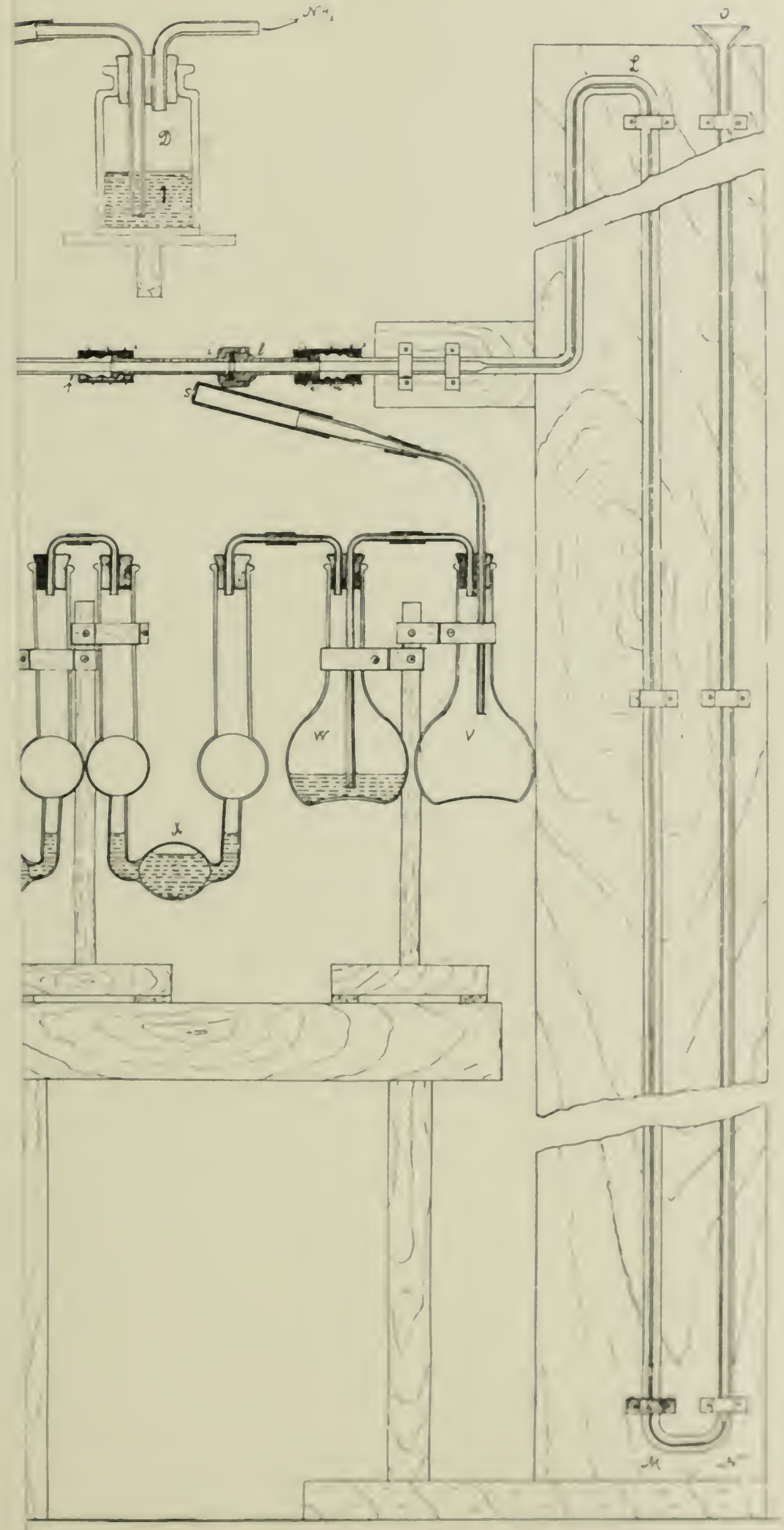
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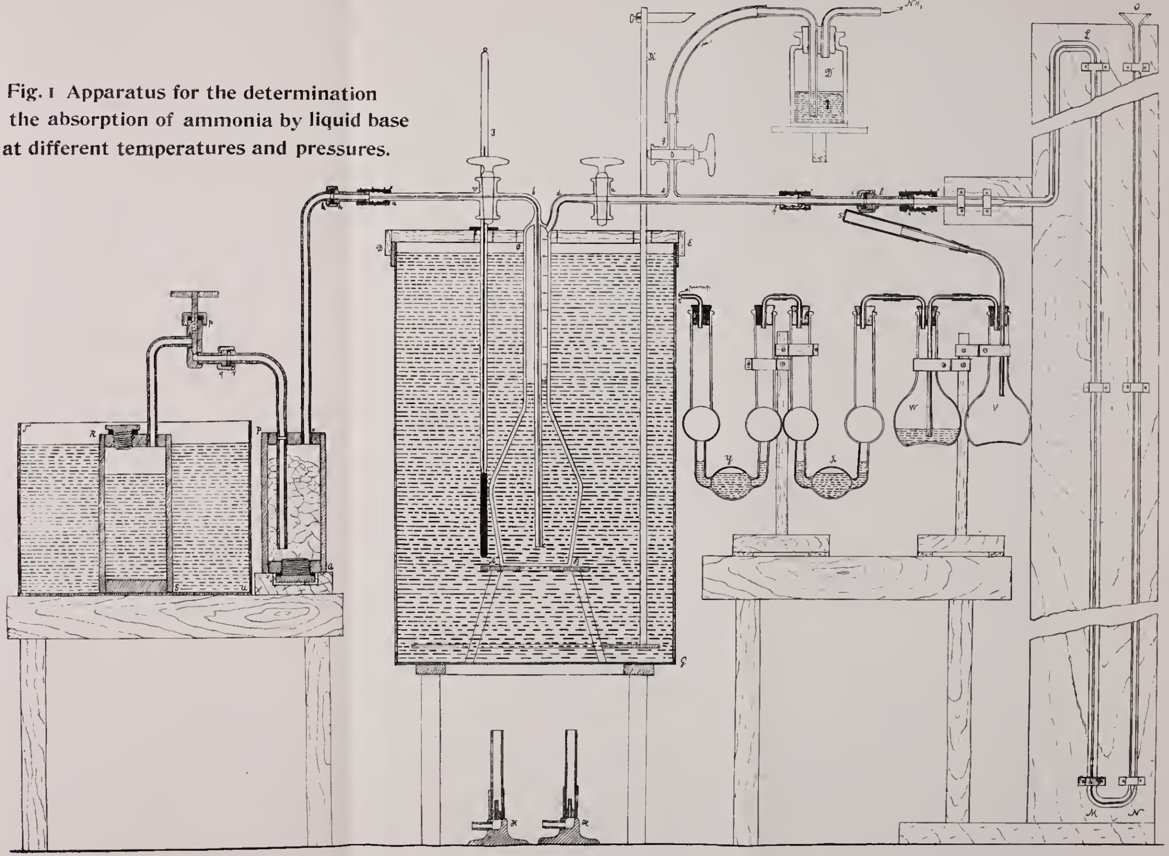
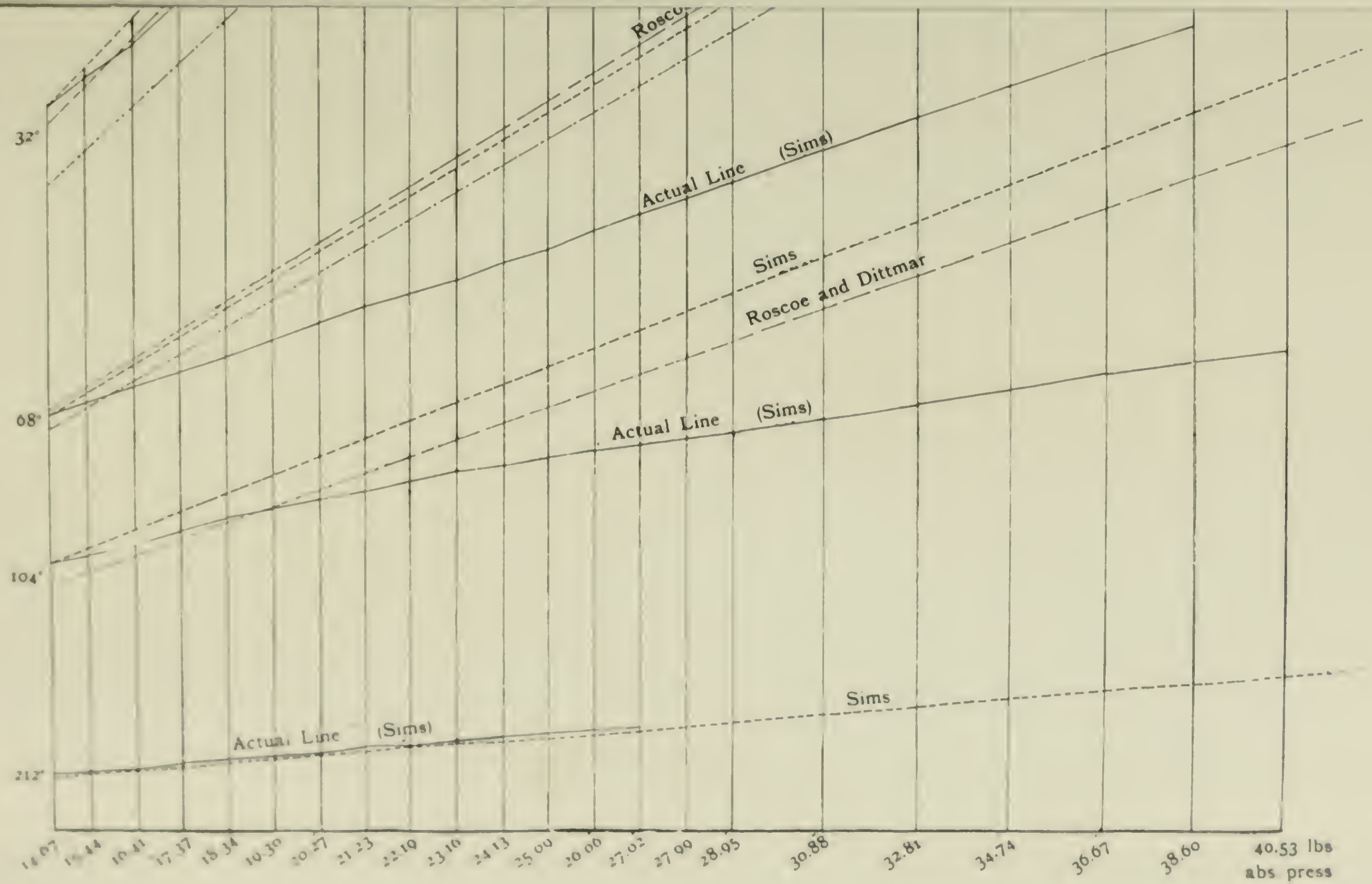
Fig. 1 Apparatus for the determination of the absorption of ammonia by liquid base at different temperatures and pressures.





Rosco
Actual Line (Sims)
Sims
Roscoe and Dittmar
Actual Line (Sims)
Sims
Actual Line (Sims)
32°
68°
104°
212°
14.07
14.44
16.41
17.37
18.34
19.30
20.27
21.23
22.10
23.16
24.13
25.00
26.00
27.02
27.99
28.95
30.88
32.81
34.74
36.67
38.60
40.53 lbs abs press

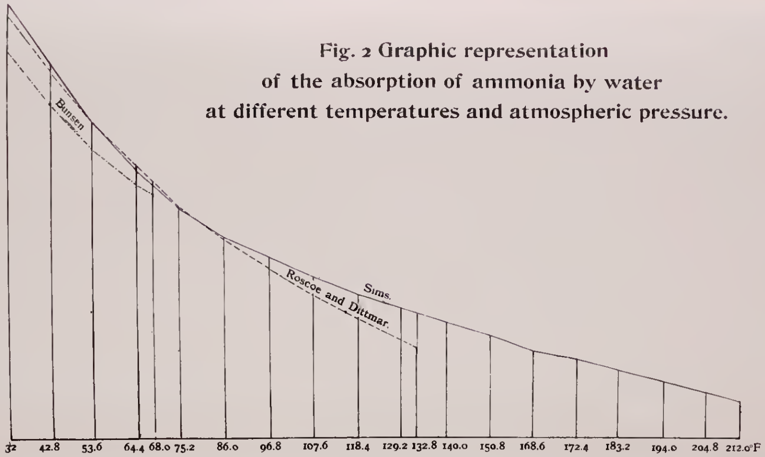
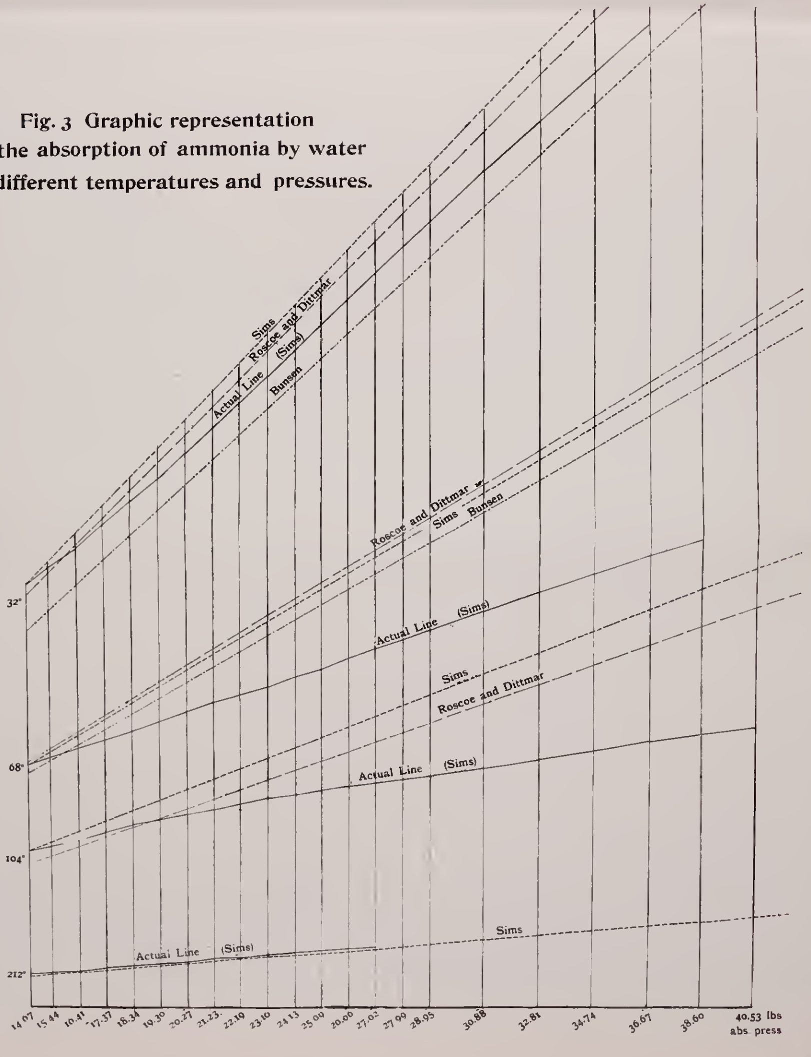


Fig. 2 Graphic representation of the absorption of ammonia by water at different temperatures and atmospheric pressure.

Fig. 3 Graphic representation of the absorption of ammonia by water at different temperatures and pressures.



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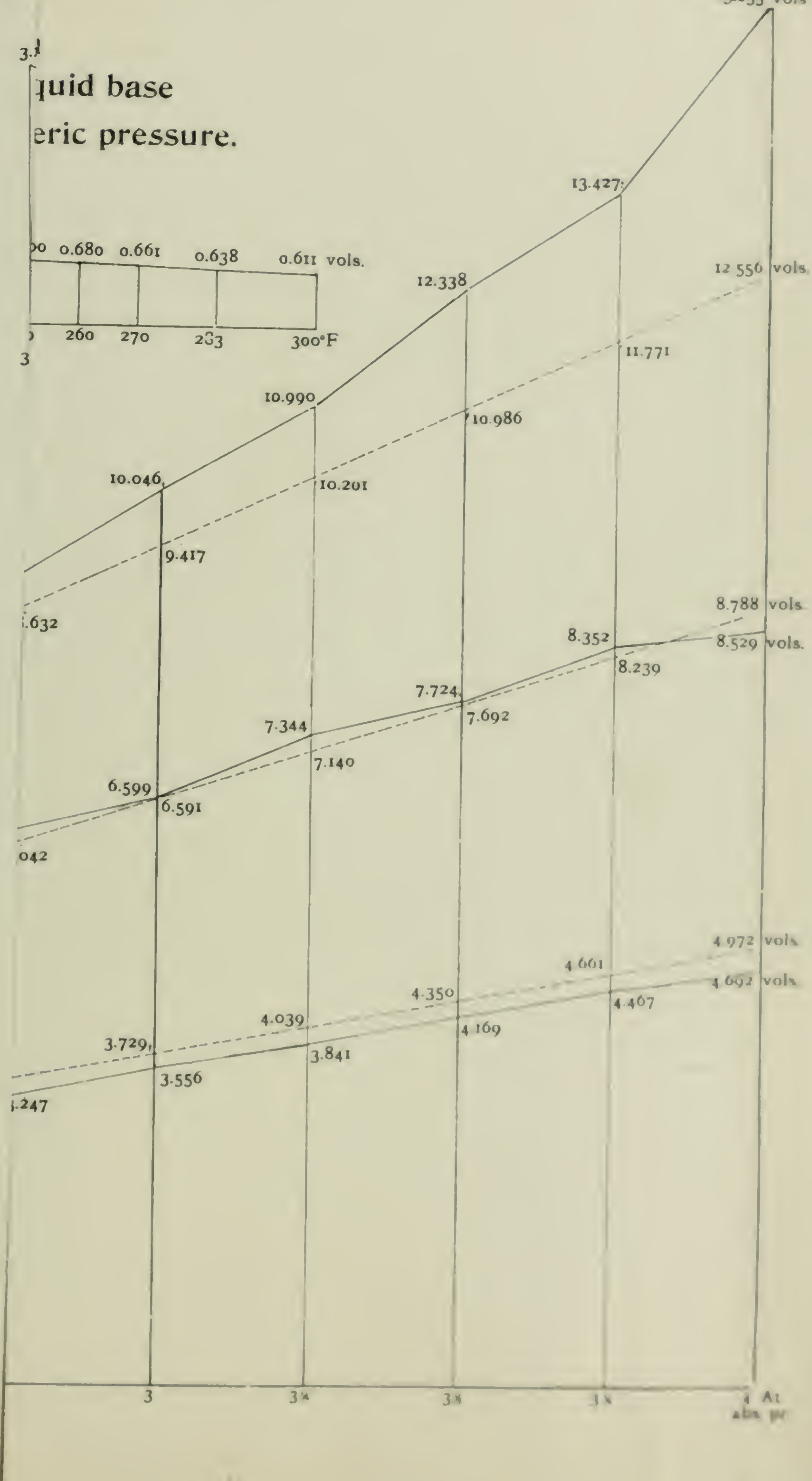

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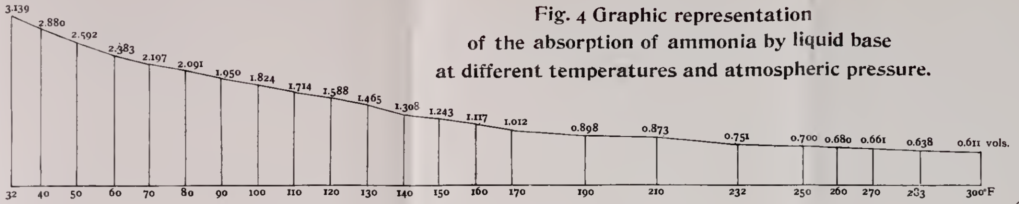

Fig. 4 Graphic representation of the absorption of ammonia by liquid base at different temperatures and atmospheric pressure.

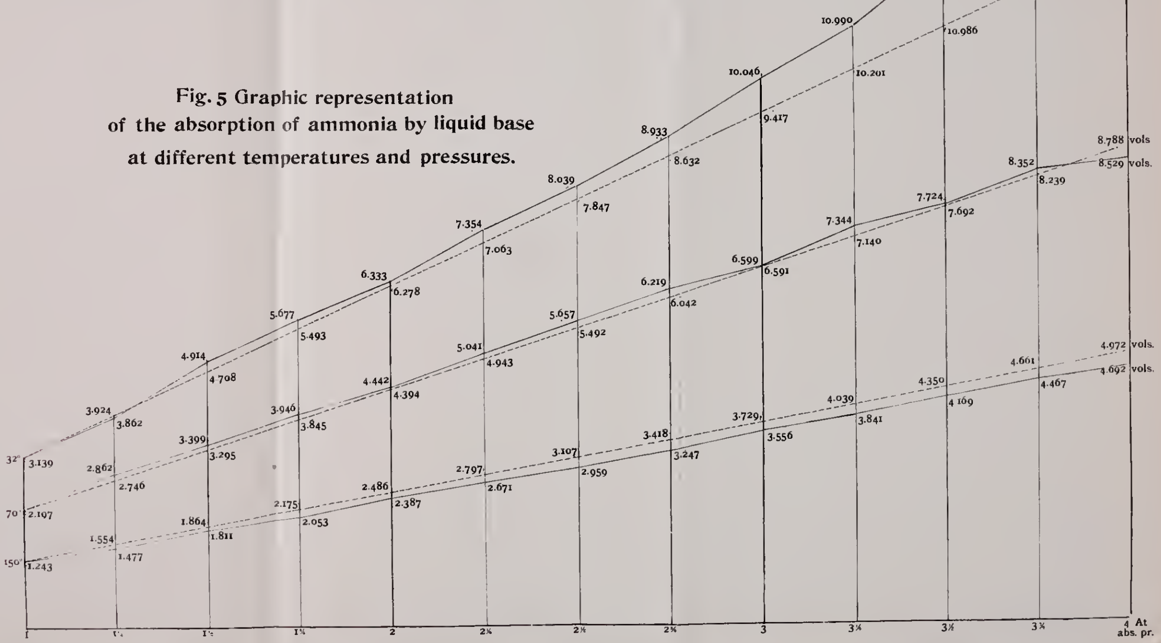

Fig. 5 Graphic representation of the absorption of ammonia by liquid base at different temperatures and pressures.

gas passes through a stratum of mineral oil in *D'*, and from there into the atmosphere. The purpose this bottle *D'* is intended for is that by the velocity with which the bubbles of ammonia pass through the oil in *D'*, the velocity of the current of ammonia passing through flask *A B C* can be judged. The pipe ends *a* and *f* are provided with bulbs and by means of strong pieces of rubber-hose (the resistance of which is strengthened by brass-sheathings wrapped over them) connected with two short pieces of iron pipe which are provided on their other ends *h* and *i* with a thread and a nut, fitting the nut *k* and the thread *l*, respectively, tightly by means of washers. The nut *k* is at the end of the pipe *k o* terminating into the top of tank *P Q* which is filled with pieces of sodium hydrate. The ammonia developed in tank *R S* passes through the contents of tank *P Q*, and is thus freed of any moisture which may be present. In order to make the development of the ammonia constant and thus avoid as much as possible any sudden turbulent eruptions of the same, tank *R S* is put in cold water contained in tank *T U*. Cock *p* is of such a construction as to allow us to regulate the quantity of ammonia entering flask *A B C* in the minutest manner. The other end of the iron pipe *l m* by means of a strong piece of rubber-hose (again strengthened by brass-sheathing) is connected with the end *n* of the mercury gauge *L M N O*. Pipes *L M* and *N O* being about two and one-half metres long, an absolute pressure of four atmospheres can be obtained without having the mercury in leg *L M* go too far down to the bend *M*, and thus without being exposed to the liability of one of the above-mentioned uncontrollable eruptions of the ammonia forcing the mercury entirely out of leg *L M*, and thus spoiling the whole test. Pipe *L M* being capillary, the diameter of *N O* being five mm. inside, an oscillation of a few millimetres up or down of the mercury in *L M* is hardly noticeable in *O N*, and thus by regulating cocks *p* and *g* the pressure prevailing during the test can be kept constant within a few millimetres.

When the contents of flask *A B C* have the desired temperature, the whole apparatus is put together as shown in

Fig. 1. Ammonia is allowed to pass through the oil until all air in the neck of *A B C*, in bottle *D′* and in the gauge, is displaced by ammonia, and then mercury filled into the gauge to a convenient height. If the test is to be made at atmospheric pressure, nothing is to be done but to regulate the current of ammonia in such a way that the mercury column is at the same height in both legs of the gauge, but the pipe *d c g* having a much larger diameter than *a b c*, hardly any regulation of cock *p* is necessary. If the test is to be made at higher pressure the two cocks *p* and *g* are handled until the pressure indicated by the gauge is the desired one, it being taken care that a properly strong current of ammonia escapes through *D′*. According to the prevailing temperature and pressure it takes from one-half to two hours, until the liquid base is entirely saturated with ammonia. This condition being obtained, cocks *u* and *v* are closed in the very same moment, and *k* is disconnected from *h*. Then *i* having been disconnected from *l* and by means of the rubber-hose *s* having been connected to the absorbing apparatus, cock *u* is opened. As soon as the first turbulent escaping of ammonia is over, cock *v* is opened and a slow current of pure air is conducted through the whole apparatus, the linseed-oil in tank *D E F G* being heated up during this time at about 300°. Thus all ammonia that was absorbed by liquid base is conducted into the absorbing apparatus, where it is transformed into ammonium chloride, *W X* and *Y* being filled with diluted muriatic acid. If the test has been made at higher pressure and the absorbed ammonia is drawn off, larger or smaller quantities of liquid base are always forced out of flask *A B C*, and these are retained in the empty bottle *V*, thus not interfering with the formation of pure ammonium chloride in *W X* and *Y*. It takes about three hours until the last traces of ammonia are obtained in the receivers. The weight of the ammonia which had been absorbed by the oil and from it the volume of the same calculated at 32° and normal pressure, is determined in the usual way. From the volume thus obtained the volume of ammonia which at the end of the test was above the liquid base in the graduated neck of flask *A B C*,

is to be subtracted. As it is under the pressure and temperature, at which the test was made, its volume at 32° and normal pressure is to be calculated. Then by dividing the cubic centimetres of ammonia really absorbed by the oil, by the cubic centimetres of liquid base used in the test, the volume of ammonia absorbed by the unit of liquid base is obtained. For mechanical reasons, it is practically impossible to keep the pressure exactly at the point at which the test was intended to be made, and the absorption took place at a pressure of a few millimetres more or less in almost all tests made. From the results obtained with the pressures prevailing we obtain the figures for the pressures intended by application of the above-cited law for the absorption of gases by liquids at different pressures. The following is an example how this calculation was made:

Temperature at which the test was made, 150°; absolute pressure prevailing, 1906·0 mm.; absolute pressure intended, 1900·0 mm. = $2\frac{1}{2}$ atmospheres; volume of liquid base used in the test, 559·0 ccm. at 150°. Consequently at the end of the test $600 - 559 = 41·0$ ccm. of ammonia at 1906·0 mm., absolute pressure, and 150° are above the oil. These are equal to 82·7 ccm. at 32° and normal pressure.

The weight of ammonium chloride yielded is 4·2050 grammes = 1·3360 grammes = 1754·6 ccm. of ammonia at 32° and normal pressure. The 82·7 ccm. of ammonia abovementioned being subtracted, $1754·6 - 82·7 = 1671·9$ ccm. of ammonia were in reality absorbed by the 559·0 ccm. of liquid base or 2·990 volumes by the unit. If 2·990 volumes are absorbed at 1906·0 mm.,

$$\frac{2·990 \times 1900·0}{1906·0} = 2·981 \text{ volumes}$$

are absorbed at an absolute pressure of 1900·0 mm.

By calculations based on the above data, Mr. A. Siebert, Superintending Engineer of the De La Vergne Refrigerating Machine Company, found that the volumes of ammonia absorbed at temperatures between 80° and 300° F. can approximately be calculated by the formula:

$$d = 3·139 - 0·023972\,(t - 32°) + 0·00008073\,(t - 32°)^2 - 0·0000000988\,(t - 32°)^3$$

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, March 1, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 1, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, thirty members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and clerical work, which were approved and ordered paid.

The Committee on Admissions reported one election to membership since last meeting.

Mr. C. W. Pike read a paper on "The Constant Shunt Method for the Measurement of Continuous Currents," with blackboard illustration. Referred for publication. In discussion thereon, Mr. Carl Hering stated that this method had been used successfully at the Munich Exhibition of 1882, and by himself at the Institute's Electrical Exhibition of 1884. In the latter case copper wire was used throughout, making the rate of temperature variation more regular. Mr. Willyoung also stated that he had used this method satisfactorily.

Prof. E. J. Houston read a paper on "Cerebral Radiation" which was discussed at some length and referred for publication.

Mr. Carl Hering gave some data submitted by the Oerlikon Works for the power-transmission plant at Niagara. The current furnished would be equally suitable for motors, arc and incandescent lights. The dynamo is a three-phase, separately-excited machine of 5,000 horse-power, and ninety-six per cent. efficiency. Its drum armature is made up of copper bars, is ten feet in diameter, and, running at 250 revolutions per minute, will furnish a current in each of the three coils of 2,000 ampères, at 600 to 700 volts. The current from each machine feeds through two 2,500 horse-power transformers, capable of reducing from 25,000 volts. Cost of the line to be $20,000 for 32,000 metres, to carry up to 10,000 horse-power. Total estimated cost, including generators, exciters, transformers and lines, to be $180,000.

A query from the Question-Box regarding the temperature coëfficient of a Weston voltmeter was discussed at some length, and satisfactorily answered.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

RESISTANCE STANDARDS: THEIR MANUFACTURE AND ADJUSTMENT.

By Elmer G. Willyoung.

[*Read at the stated meeting, held November 3, 1891.*]

I shall speak to you for a very brief time this evening on the subject of electrical standards of resistance. The standard of resistance is, to my mind, by far the most valuable standard with which we have to do in actual work. Considering only the quantities involved directly in Ohm's law, which are about the only quantities of any particular value or meaning to four electricians out of five, the standard of resistance is almost the *only material* standard which we can possess. The unit of current is a standard but it is a standard which only exists by definition and is not an actual tangible and physical thing, while the standard of E.M.F. which shall give an exact unit or multiple of a unit is yet to be discovered; a standard cell, to be sure, giving a definite E.M.F. at a definite temperature and whose rate of variation with temperature is accurately known, is now a comparatively easy thing to secure, but the care necessary in its use together with the decimal value of its E.M.F. are both considerably against its being rated as high, practically, as the standard of resistance. It must also be borne in mind that, having a standard of resistance, we may obtain the value of any E.M.F. by the solving of $E = CR$ where C is known from the amount of electrolytic deposition taking place in a given time out of a suitable solution; the amount of copper, silver, or other metal deposited out of such a solution in a given time by a given current being always a definite and exact one to be found in any text-book upon the subject.

The standard of resistance, as generally known, is a length of wire of one kind or another, wound upon a spool, mounted in a convenient case to protect it from injury and moisture, and having its resistance at some given temperature definitely determined; a true standard also has its rate of variation of resistance for change of temperature accurately known. Sometimes one coil is mounted up alone and sometimes many coils of different values are put up in the same mounting.

In the manufacture of standards of resistance a great many qualities are required of the resistance wire which shall be used. It should have high specific resistance, in order that the standard may not have too much bulk; it should have as small a temperature coëfficient of resistance as possible, in order that its value may be easily obtained at any reasonable temperature without the making of troublesome calculations; it must not change its resistance in time; it must not be oxidizable by the air or by the medium in which it may be enclosed, since this would change the constitution and hence the resistance of the wire; and it must be of a hardness suitable for handling in manufacture and adjustment without injury. The requirement of high specific resistance immediately compels us to reject copper, iron, aluminum, silver, and all other pure metals except lead, antimony and bismuth. The softness, difficulty of working, and high temperature coëfficient as well as many other reasons would throw these last three out of the account. The matter of temperature coëfficient alone, in fact, would compel us to reject all pure metals since they all increase roughly about twenty-five per cent. in resistance between 0° and 100° C., except iron, which increases about forty per cent. We are, therefore, led to try alloys. Dr. Matthiessen, chairman of the sub-committee (of the Committee on Electrical Standards of the British Association), from 1862–65, having in charge the investigation of the properties of wires with reference to the selection of a suitable one to be used in the standard of resistance, decided upon by the British Association and now known as the B. A. Ohm, examined very exhaustively a large number of wires, among which were pure iron, silver, copper, thallium and other metals, and a great many alloys; he finally concluded that silver alloyed with 33·4 per cent. of platinum was the best alloy obtainable. This alloy, known as platinum silver, is still used by English makers; it has a specific resistance of twenty-four microhms and a per cent. variation per degree C. of $\frac{31}{100}$. In selecting this alloy we see that the requirements of high specific resistance and low temperature coëfficient have both been observed, the resistance of platinum silver being about sixteen times that of copper and its temperature coëfficient less than $\frac{1}{100}$ that of copper.

With reference to the constancy of resistance in wires it may be well to mention that many metals and alloys seem to alter in electrical resistance with time, or on being subjected to change of temperature. In an investigation carried on by J. Bergmann, a German electrician, in the latter part of 1889, he reports that, after raising to and maintaining at 300° C. for one hour and then cooling, the resistance of several substances changed as follows:

	Per Cent.
Copper decreased,	2·4
Aluminum "	5·0
Magnesium "	6·8
Zinc "	2·4
German-silver increased,	$\frac{2}{10}$

Mr. Tomlinson, a little earlier, found a somewhat similar result in the case of iron wire, which decreased in resistance about one-quarter per cent. after several heatings to 100° C., and subsequent cooling. Dr. Matthiessen, in the investigations previously alluded to, found a considerable time change in a number of the alloys and wires, which he experimented upon. It may be of interest to state here that three of the original platinum-silver coils determined by the British Association through Dr. Matthiessen and his colleagues at the time of the adoption of the B. A. Ohm were found last year, when carefully examined, to have developed an increase of resistance of about six parts in 10,000, or about $\frac{6}{100}$ per cent., quite an appreciable amount as standards go. The committee having these last comparisons in charge suggested that this change in resistance was only temporary, and due to strains in the wire produced by lowering it to 0° C., at which temperature the measurements were made; they have, however, not yet been able to verify this idea. A time change is, however, to be noted in a large number of metals and alloys where strains are not taking place. This time change in resistance, as Dr. Matthiessen suggested, is probably very largely due to a gradual annealing effect, as it is particularly noticeable in hard-drawn wires. It has also been observed to be in a marked degree a property of wires containing zinc and to be lacking, except to a very small extent, in wires free from zinc; here it is possible that zinc may gradually crystallize out, since it does easily crystallize, and the homogeneity of the wire thus being altered, the change in resistance may be accounted for.

It is almost self-evident that the resistance of a metal or alloy is a function of its density; hence, all causes tending to change the density of the resistance metal will also tend to change its resistance. It is quite reasonable to expect, therefore, that an increase of resistance should be observed after a wire is wound upon a spool. A wire wound up on a spool not over eight times its own diameter will increase from one-half to two per cent. in resistance; a part of this increased resistance is due to the increased hardness caused on the inside of each turn, by the bending stress, and hence gradually falls away as the wire slowly anneals. For this reason, it is unsafe to send out a resistance standard as correct until several months have elapsed after winding.

Several years ago a wire was brought out in England known as "platinoid." It was said to be an alloy composed of ordinary German-silver with one or two per cent. of metallic tungsten added. It has a specific resistance of about thirty-two microhms and a temperature coëfficient of $\frac{22}{100}$ per cent. per degree Centigrade. I have analyzed this several times but have never been able to detect any tungsten; two or three friends have done the same with the same result. Whether or not any tungsten is used as the wire is now made, is, therefore, not certain. During the week since reading this paper, I have been informed by an electrician that the tungsten "burns out" in the process of manufacture. The properties of this alloy are, however, about as reported. It is nearly as cheap as German-silver, and during the time over which my own observations have extended shows no time change; at least if any change has taken place in the coils in our possession, is has been by less than $\frac{1}{100}$ per cent. The wire is hard, practically non-oxidizable and easily handled. It is now being used in all the standards sent out by Queen & Co., and proves satisfactory in every way. I have here in my hand a wire recently sent me by the Aluminum Brass and Bronze Company, of Bridgeport, Conn., and claimed by the manufacturers to have thirty-five times the resistance of copper together with an extremely small temperature coëfficient, less than $\frac{1}{10}$ that of German-silver. I have not had an opportunity to test the accuracy of these statements as yet, having been too busy with other work, but hope soon to be able to do so. According to the *Electrical Engineer*, of October 21, 1891, there is also claimed for this wire a tensile strength of 70,000 to 100,000 pounds per square inch, with eighty twists in six inches, and with a lower resistance, a tensile strength up to 140,000 pounds per square inch You see it is of a pale-rose color and looks as if it might contain considerable copper. I suspect it is a variety of manganese-copper made up of about seventy per cent. of copper and thirty per cent. of manganese, with perhaps a small percentage of nickel. Mr. Edward Weston experimented on some of these alloys a couple of years ago and found one of them to have a negative temperature coëfficient; his statement to that effect was received with considerable incredulity at the time, but has since been thoroughly verified. According to Drs. Feusner and St. Lindeck, in *Zeitschrift fur Instrumenten Kunde*, February, 1891, an alloy composed of seventy per cent. copper and thirty per cent. manganese had a resistance of about five times that of German-silver and a temperature coëfficient of but $\frac{4}{1000}$ per cent. per degree Centigrade, while an alloy of seventy-three per cent. copper, three per cent. nickel, and twenty-four per cent. manganese had a specific resistance a little less than three times that of German-silver, and a *negative* temperature coëfficient of $\frac{3}{1000}$ per cent. We see, hence, that it ought to be entirely possible to obtain a wire having a zero coëfficient, *i. e.*, not changing resistance at all for change of temperature by properly combining the constituent metals of this alloy. The obtaining of such an invariable standard is a "consummation devoutly to be wished" in electrical work as accurate work is very troublesome and tedious where long decimal coëfficients have to be applied, and this becomes particularly the case where several sets of coils are used in the same investigation having different temperature coëfficients. Dr. E. S. Nichols, of Cornell University, and others have made successful attempts to obtain resistances having a zero coëfficient working along another line; they have taken a rod of carbon and soldered to its extremities a length of wire of some metal or alloy; since carbon decreases and wires increase their resistance with rising temperature, it is evident that by using a suitable wire and proper proportions a combination might be found which when placed in a circuit in parallel would remain of the same resistance at any temperature. The difficulty of soldering to carbon as also the care necessary in adjusting prevent, however, such resistances from becoming commercial possibilities; the carbon is also too sensitive to changes of pressure and to strains.

A strictly standard resistance is, according to the practice of the best makers, adjusted to anything within from $\frac{1}{10}$ to $\frac{1}{100}$ per cent. of absolute accuracy. A *single* coil would not be considered a "standard coil" unless it were accurate within from $\frac{1}{50}$ to $\frac{1}{100}$ per cent. absolute accuracy. To obtain this high accuracy of adjustment it is easily seen that very exact methods of measurement must be employed; should we attempt to measure an inch within this limit of error, the error could not be over $\frac{1}{10000}$ inch, an exceedingly small quantity. Various methods have been suggested and employed by different parties at different times. An apparatus designed by Prof. Fleeming Jenkin, and used somewhat by the British Association Committee in 1862, consisted of essentially, an ordinary Wheatstone's Bridge with the connection between two adjacent arms, consisting of a short, straight length of resistance wire. If, now, one galvanometer contact be on this straight wire and the other at the junction of the two opposite arms of the bridge, and *S*, one of these opposite arms, be the coil to be adjusted to R, the other of the opposite arms, and the arms adjacent to the straight wire be designated C and A we will have

$$\frac{C}{A} = \frac{R}{S}$$

we now interchange R and S and have

$$\frac{C}{A} = \frac{S}{R}$$

this will demand a new position of the galvanometer contact upon the straight wire and the distance moved over on the straight wire is a measure of the difference in resistance between R and S.

Suppose that C and A each have 100 inches of the same wire as the straight wire and that we have had to move over one inch in reversing R and S, then R and S agree within one per cent. Now we adjust S closer to R and substitute for C and A two new coils C' and A' each of 1,000 inches wire. If now we again adjust so as to move over one inch in reversing we are within $\frac{1}{10}$ per cent. of accuracy; and so by continually adjusting S to R we may obtain gradually closer approximations to accuracy if we, at the same time, substitute other coils for C and A. But this process is, at the best, but a cut-and-try one and exceedingly tedious. A complete description of this method and convenient apparatus will be found on p. 38, of *Reports of Electrical Standards*, published by Spon.

I have here a piece of apparatus first designed several years ago during my student days. It is a modification of an arrangement devised by Prof. S. P. Thompson, and described in *Stewart & Gee*, 2d vol., p. 160. The one I have here was first suggested to me by Prof. H. S. Carhart, of Michigan University, and has since been somewhat modified by myself. If we take an ordinary slide wire bridge having four openings for coils at the back and (the slide wire being in front) fill these spaces, beginning at the left, with coils designated P R_1 R_2 and Q, respectively, connect the battery from between P and R_1 to between R_2 and Q, and the galvanometer from between R_1 and R_2 to a point on the slide wire, we have substantially the method which is known as the Carey-Foster method. Designating the resistance of copper connector at the left by r_1 and of copper connector at the right by r_2 and letting P be the resistance of unit division of the wire.

$$\frac{R_1}{R_2} = \frac{P + r_1 + X_1 \rho}{Q + r_2 + (L - X_1)\rho} \qquad (1)$$

where X_1 is the reading on the bridge wire and L the total number of divisions. Reverse the position of P and Q and we have

$$\frac{R_1}{R_2} = \frac{Q + r_1 + X_2 \rho}{P + r_2 + (L - X_2)\rho} \qquad (2)$$

From (1) we have

$$\frac{R_1}{R_1 + R_2} = \frac{P + r_1 + X_1 \rho}{P + Q + r_1 + r_2 + L \rho} \qquad (3)$$

and from (2) we have

$$\frac{R_1}{R_1 + R_2} = \frac{Q + r_1 + X_2 \rho}{P + Q + r_1 + r_2 + L \rho} \qquad (4)$$

From (3) and (4) we get

$$Q + r_1 + X_2 \rho = P + r_1 + X_1 \rho$$

$$Q - P = \rho (X_1 - X_2)$$

which is an expression independent of the resistance of the end pieces of the bridge, being merely the resistance of that portion of the wire over which we must move in obtaining our two balances. Thompson's device is merely for quickly and conveniently interchanging coils P and Q; with it we must change the position of four copper connectors in four mercury cups; this is tedious and increases the danger of a change of temperature between the adjustments. The modification which I have here has reduced these changes to two which can be almost instantly made. With this device and a carefully calibrated bridge wire it is an extremely simple matter to attain an accuracy of $\frac{1}{100}$ per cent., while much higher percentages of accuracy may be gotten with care. Of course, in this method the coils P

and Q must be at a definitely known temperature which shall not change during the taking of the two readings; hence, the two coils are placed in well stirred water or oil baths. The other coils R and S are wound together and left in the open air as, if they change at all, they will probably change about equally and the result be of no appreciable importance. This device is also the best thing to use in determining temperature coëfficients of wires; a length of wire is wound up on a spool, immersed in oil at a definite temperature and compared with a standard., The temperature of the oil is then raised and the resistance of the wire again determined; knowing the difference of temperature and the change of resistance the temperature coëfficient follows.

ON THE VARIABLE ACTION OF TWO-COIL SOLENOIDS.

By WM. S. ALDRICH, Johns Hopkins University, Baltimore, Md.

[*Read at the meeting of the Electrical Section, held February 2, 1892.*]

The Two-coil Solenoid Electro-magnetic Mechanism produces a double-acting reciprocating movement of an iron core or plunger, when the coils are variably energized by a pulsating current, causing the induction to rise from zero to a maximum alternately in each coil. The action of the plunger under the influence of the two magnetic fields of force, other conditions being equal, will vary according to whether the two solenoids act with or against each other. The respective movements of the plunger are not only very different in each case, but the maximum pull in either direction towards the central line between the two coils is greater in the former arrangement than in the latter, as will be seen by referring to the plotted results of the experiments under these two conditions.

A preliminary experiment was made with a variable current obtained by an adjustable resistance, to determine the maximum pull, its variation, the movement of the plunger when under maximum pull, and also when exerting no pull, or when in a position of equilibrium. In the experiments of which the results are shown graphically, the pulsating current was obtained by a rotating brush * moving around the commutator of a dynamo, and the action of the two coils was examined with reference to:

(1) The combination (the differential coil-and-plunger of Sylvanus P. Thompson's classification), consisting of the two solenoid coils as two parts of one coil, traversed by a pulsating current of variable intensity in each part, and giving rise to a resultant magnetic field from the combination of the two variable-intensity electro-magnetic stresses of like character, and constant in direction.

(2) The combination operating as two distinct solenoids, producing resultant stresses in the ether medium from the two variable-intensity electro-magnetic stresses of opposite character and constant in direction.

The Pulsating Current Obtained by Variable Potential through constant resistances, will give quite a steady pull and almost regular reciprocation of the plunger, from the regular variations of potential, and so of current and of magnetizing effect of the two solenoid coils. But, whereas the electrical resistance of the solenoid coils may be considered constant under all ordinary conditions (excepting the slight variations due to the heating effect of the current), the magnetic resistance or reluctance of the iron core is quite variable with the intensity of magnetization. So that while a regular variation of potential may produce a regular undulation of the current passing through the solenoid coils, the resultant effect upon the iron core plunger may vary within wide limits; also, according to the counter-electro-motive force, depending largely upon its speed of reciprocation, and its position in the field of force, which position may be more or less controlled by external mechanical forces.

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* As in Van Depoele's double-acting pulsating current electro-magnetic reciprocating mechanism, for claims and applications of which see United States Patents, No. 422,855, of March 4, 1890; No. 458,873, of September 1, 1891; No. 461,294 and 461,295, of October 13, 1891.

The Two-coil Solenoid in these Experiments consisted of two coils, of 200 turns each, of No. 14, B. & S., double-cotton covered copper wire; both coils were wound in the same direction, on a thin brass tube, of 0·625 inch outside diameter, and 4·1 inch long; the coils themselves were each 1·9 inches long, and separated by a 0·1 inch fibre disk, and protected also at the outer ends by 0·1 inch fibre disks. The iron core forming the plunger was 0·5 in diameter, and 2·25 inches long, of soft, slightly annealed wrought iron, capable of carrying about 15,000 lines per square centimetre just below the point of saturation. The construction was not iron-clad. The pull was measured by a sensitive spring balance; and the plunger was nominally at rest when readings were taken—it being in static equilibrium under the action of the spring balance and the electro-magnetic stresses.

Preliminary Experiment; Potential Varied by Resistances, introduced in circuit with the solenoid coils, causing a variable current to be supplied to them, from a constant storage battery supply of twelve ampères and 1·75 volts. The inner ends of the solenoid coils connected to a movable or sliding contact along an adjustable resistance, and the outer ends connected to the outer terminals of this resistance, joining up the two solenoid coils as two parts of one coil, forming a differential coil-and-plunger traversed by a current of variable potential.

(*a*) Sliding contact dividing the adjustable resistances in the ratio of four to four (equally) between the two solenoid coils; maximum *downward* pull, three ounces.

(*b*) In the ratio of five (top solenoid) to three (bottom solenoid); 2·7 ounces.

(*c*) In the ratio of six (top) to two (bottom); 3·1 ounces.

(*d*) In the ratio of seven (top) to one (bottom); 3·3 ounces.

(*e*) In the ratio of eight (top) to zero (bottom solenoid coil cut out); 3·3 ounces.

The 2·25 inch plunger, under maximum downward pull, was almost invariably in one position, during this quarter-cycle of operations; its centre being about 1·725 inches above the centre line of the 0·1 inch fibre disk between the two coils; that is, a little more than half-way in the top coil.

The zero position of the centre of the plunger moved upward 0·95 inch—from 0·075 inch *below* the centre line of the fibre disk between the coils (for the four-to-four combination of adjustable resistances), to 0·875 inch *above* this line, when the bottom coil was cut out. This latter position should probably have been 0·95 inch (which is one-half the coil length of 1·9 inches), above the bottom of the top coil; that is, the plunger in normal position of equilibrium in one or the other coil alone, of about the same length, should be about central with that coil under all ordinary conditions. While, when both coils are equally energized the plunger is normally central between them, for thin separating disks, yet the two coils may be so far separated, longitudinally, that the zero position is more or less indeterminate. Other conditions being equal, the plunger not being exactly central between the two coils, shows that the external resistances introduced were not exactly equal in the four-to-four combination. Sylvanus P. Thompson speaks of the maximum pull of a single coil on a plunger of the *same length* of the coil, as occurring when the plunger is about half-way in; and of the differential action of the two coils in the above case, as being simply due to the difference between the ampère turns of the two separate coils.

Experiments with Rotating Brush Method of producing variation of potential and so of current in the solenoid coils. The diagram of connections is shown in *Fig. 1*. The dotted line connection, with voltmeter in circuit, shows the method by which the distribution of potential around the commutator was obtained, giving what Sylvanus P. Thompson has called the integrated curve of potentials. The ordinates of this curve (shown on line E of the plotted results) at any position of the rotating brush around the commutator, gives the total or integrated potential from the fixed brush terminal up to that point. The machine used in the experiment was a one horse-power motor, separately excited and run as a dynamo, at about 2,600 revolutions per minute (normal speed, 2,750). The equal resistances R' and R'' were introduced in the external circuit, which showed about forty-five volts and eight ampères when the rotating brush was off the commutator. Owing to small variations in the speed of driving pulley, and slight unsteadiness of the exciting current supplied to the field coils, there were slight variations in the external circuit of the machine. The commutator had forty bars, and readings were taken with the rotating brush successively on each bar.

Two Sets of Experiments were made with this rotating brush combination:

(1) With the two coils of the solenoid operated as a differential coil-and-plunger, of which the results are plotted on *Sheet I*.

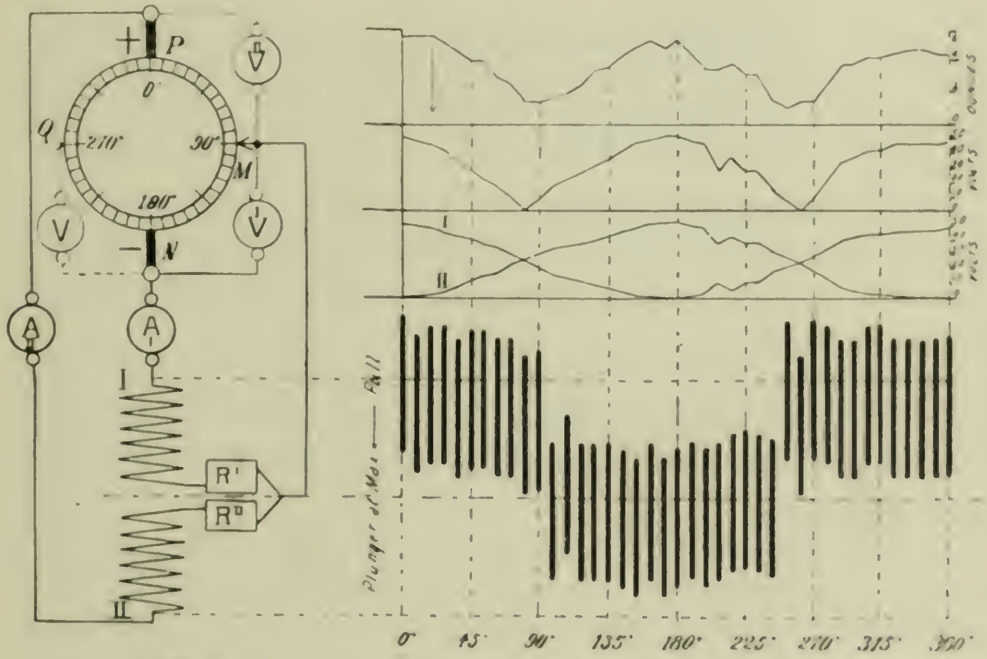


Fig. 1. Fig. 2.

Diagram of connections, and successive positions of plunger.

(2) With the two coils operated as separate solenoids with opposing magnetic fields, of which the results are plotted on *Sheet II*.

The effective ampères, line *B*, and effective volts, line *D*, were obtained for the different points around the commutator by subtracting the corresponding ordinates of the curves on lines *A* and *C*, respectively. The portion of these curves *B* and *D*, on *Sheet I*, between 81° and 261°; and on *Sheet II*, between 72° and 270°—represent negative values, corresponding more or less to the variations of potential and of ampère-turns chiefly effective in the bottom coil *II*, while the remaining portions of *B* and *D* represent the positive values, which are chiefly effective in the top coil *I*.

The curve on line *E* (the same on each sheet) represents simply the variations of the integrated curve of potentials, when there was no external circuit to the machine.

The curves on lines *F* and *G* represent the paths of the movement of the centre of the 2·25 inch plunger, under maximum pull—the former, *F*, when the maximum pull is upward from bottom coil *II* towards top coil *I*; and the latter, *G*, when the maximum pull is in the opposite direction, from *I* toward *II*.

Line *H* represents the successive positions of the 2·25 inch plunger when in zero position of static equilibrium between the electro-magnetic stresses of the fields of coils *I* and *II*.

The curves on lines *K* and *M* represent the maximum pull in each direction; on *K*, the upward pull, from coil *II* toward *I*; and on *M*, the downward pull, from coil *I* toward *II*.

Fig. 2 shows the movement of the position of maximum downward pull, as indicated on line *G*, of *Sheet I*, the heavy lines diagrammatically represent the successive positions of the plunger.

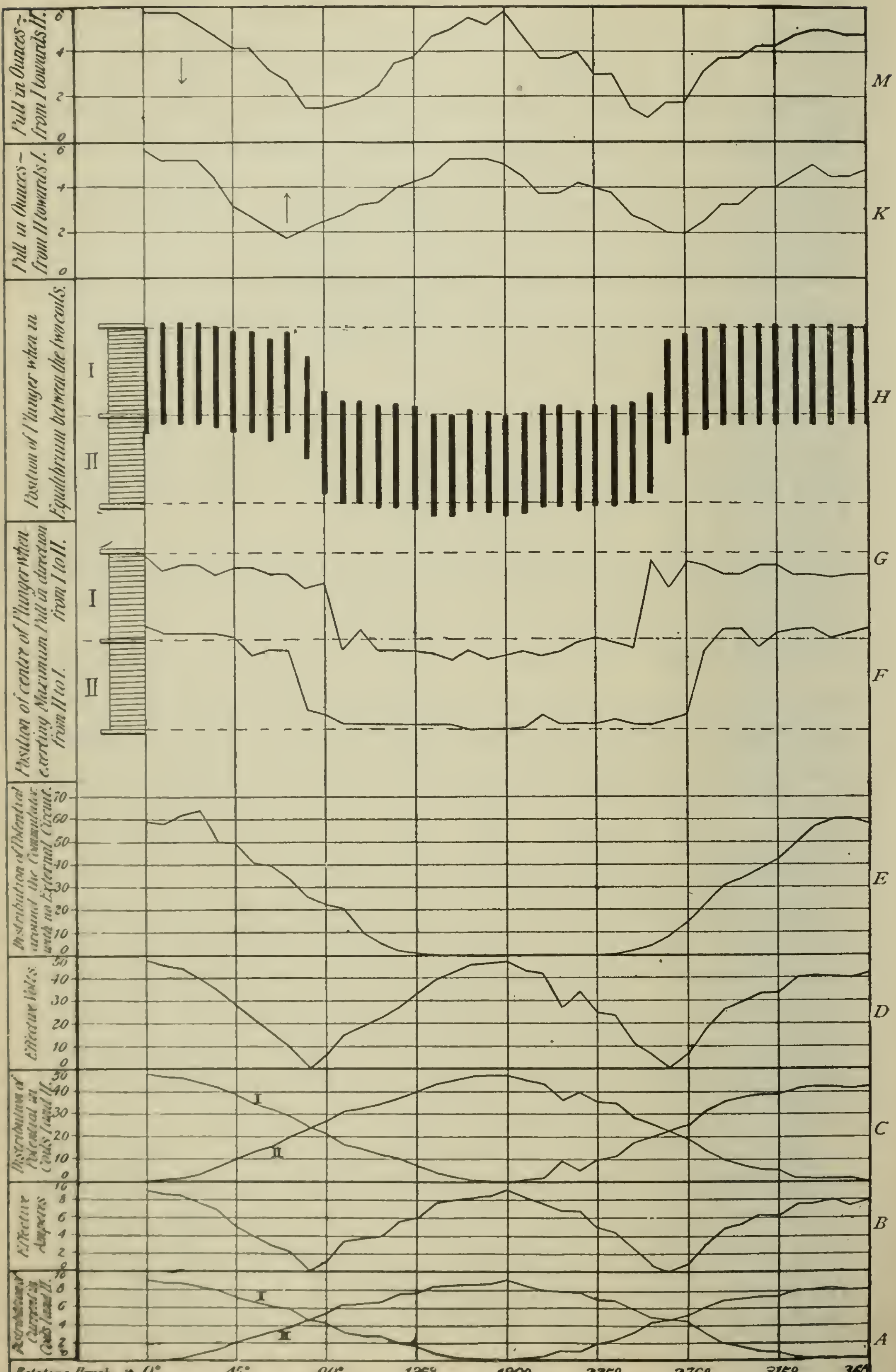
The Movement of the Plunger is brought about by the effort of its iron core to embrace the greatest possible number of lines of force; and, therefore, so to place itself that it shall have the maximum induction, and shall cause the least deformation of the magnetic circuits. When it is in a zero position between the two coils, it exerts no pull and has no tendency to move into one or the other of the coils; and, if external force is applied to move it out of this position, it will return unto it again when that external force is removed—coming back to rest, as it were, in a position of more or less stable equilibrium. This position falls within the two coils, as an interior position of zero pull; and between it and the exterior positions of zero pull of each coil, respectively, there occur the positions of maximum pull in each direction. These have also a movement, somewhat similarly phased to that of the zero position. Though the plunger was stationary when readings were taken at each point, it will be seen that the movement of the rotating brush would cause a reciprocating motion of the plunger in a fixed two-coil solenoid. If the plunger is under the action of no external forces, or of balanced external forces, —being then free to move, along with the movement of the position of maximum induction, or position of equilibrium, —it will move more regularly in unison with the rotating brush, when the two coils are operated together as a differential coil-and-plunger (line *H*, of *Sheet II*), than when they are working against each other.

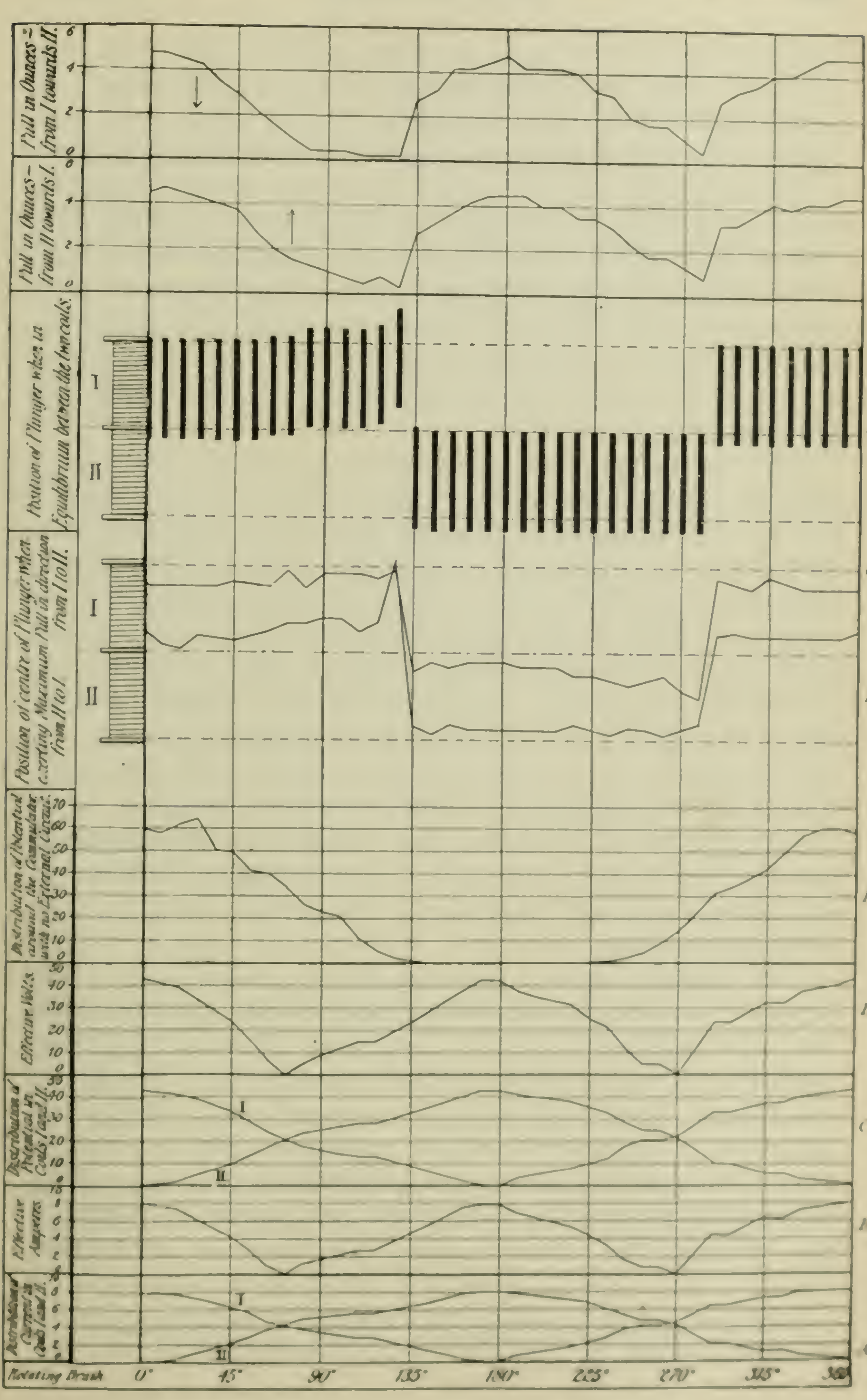
The peculiarity of the second combination is shown on line *H*, *Sheet II*. The position of equilibrium is remarkably steady at each end of the stroke. But just before beginning the down-stroke, from 117° to 135°, it takes a sudden stroke backward, and then very rapidly plunges forward to its new and temporarily settled position of equilibrium, at 135°.

From *Sheet I*, it appears that the plunger passes from one end of its stroke to the other as the effective volts and ampère-turns pass from positive through zero to negative values—corresponding to the resultant induction passing from a decreasing positive to an increasing negative effect on the plunger. But *Sheet II* shows a remarkable displacement of this position of the reversal of the resultant magnetizing effect of the two coils; from 72° the plunger is pushed farther into coil *I*, as its induction decreases while that of coil *II* increases, till the effect of the latter completely overcomes that of the former, and pulls the plunger most completely within its own range of action from 126° to 135°. The reverse operation occurs from 279° to 288° but it is not so marked as in the former.

The movement of these points of zero as well as of maximum pull will be very much affected by the character of the pulsating current supplied to the coils; the counter-electromotive force induced in the solenoid coils, and the variation of this with the rapidity of reciprocation; the character of the return-path for the lines of force, whether

Jour. Frank. Inst., Vol. CXXXIII. April, 1892. (*Aldrich. Sheet I.*)




Pull in Ounces – from I towards II.
6
4
2
0
M
Pull in Ounces – from II towards I.
6
4
2
0
K
Position of Plunger when in Equilibrium between the two coils.
I
II
H
Position of centre of Plunger when exerting Maximum Pull in direction from I to II. from II to I
I
II
G
F
Distribution of Potential around the Commutator with no External Circuit.
70
60
50
40
30
20
10
0
E
Effective Volts.
50
40
30
20
10
0
D
Distribution of Potential in Coils I and II.
50
40
30
20
10
0
I
II
C
Effective Amperes.
10
8
6
4
2
B
Distribution of Current in Coils I and II.
8
6
4
2
0
I
II
A
Rotating Brush
0°
45°
90°
135°
180°
225°
270°
315°
360°

through air or iron; and, if through iron, upon how it is disposed, whether in the simple iron-clad construction of an external shell, or in addition to this an internal shell, as in the Ayrton and Perry* tubular iron-clad electro-magnet.

Balance of the Electro-magnetic Stresses of the magnetic fields of the two coils might be effected by a combination which would produce an equal fall of magnetomotive-forces at the centre of the plunger, much in the same way as is now done in balancing the Wheatstone bridge, by arranging the resistances of the arms so as to cause an equal fall of electro-motive forces at the terminals of the indicating galvanometer.

But balancing electro-magnetic stresses is a much more difficult and delicate matter than that of the fall of potential in the arms of a Wheatstone bridge. Any application of the principle of this two-coil solenoid in a measuring instrument would require a careful determination of the combined effect of the several variable resistances in the path of the magnetic circuit, chiefly made up of the air-gap resistance and the variable reluctance of the iron core. Also the slightest movement of the plunger into or out of the resultant field of force, of the two coils, produces a variation in the line-integrals of both of these resistances. As it is not possible to eliminate the variation of the magnetic resistance with the variation of magnetization, it is necessary to make the air resistance constant by a fixed air-gap, as in the dynamo.

The Stability of the Electro-magnetic Equilibrium of the plunger, in this two-coil solenoid mechanism, depends upon the way the two coils are operated, whether producing magnetic fields working with or against each other. In the former case the plunger is practically under the influence of one field, having a movable position of maximum induction, whose movement follows closely that of the rotating brush; but if for any one position of equilibrium, the plunger be drawn aside into one or the other coil, and then released, it will slowly resume its former normal position of zero pull; the electro-magnetic equilibrium is stable. In the latter case, however, there is unstable equilibrium of the plunger under the action of opposing electro-magnetic stresses; for a slight movement of the plunger into one of the coils, from its zero position, will so far bring it into the field of maximum induction of that coil, as to cause it to take some new position, where it can best complete the magnetic circuit of that coil under whose influence it is now brought. In stable equilibrium, the plunger is wholly within the range of action of the one magnetic circuit of the two solenoids acting (differentially) as one coil. In unstable equilibrium, the plunger is partly within the range of action of each of the two opposing magnetic circuits, so that almost the slightest movement will send it rushing into the one or the other coil, in order to get into the position where it will have the maximum number of lines of induction passing through it. Moreover, line *H*, *Sheet I*, shows the stable equilibrium to be almost constant in its character; while that of *Sheet II* shows the unstable equilibrium to be variable, from the least instability when the electro-magnetic stresses differ most, at 0° and 180°—to that of greatest instability when these stresses are nearly equal, 45° to 135°, and about 270°.

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* For this and other typical forms, see Sylvanus P. Thompson's work on *The Electro-magnet.*

Industrial Applications of this Two-coil Solenoid Mechanism vary with the character of the work to be done. For pumps, reciprocating machine tools, and like operations, where a steady forward or return stroke, or both, is required, the differential coil-and-plunger of the first combination is most useful. The electro-magnetic stresses are nearly constant, resulting from a more nearly uniform intensity of magnetization of the plunger core, and giving greater maximum pull with less variation than in the second case. For quick-return motion of the plunger, in machine-tool work, the rotating brush may easily be moved around more rapidly in one portion of its rotation than in the remaining portion, giving the plunger a definite ratio of advance to return, as in the Whitworth and other quick-return motions. For electro-magnetic forging, whether by a direct hammer blow, or by the drop-forging process, riveting, rock drilling, and like operations requiring a definite hammer blow, the two coils may be connected up in opposition to each other, as in the second case. To develop greater power in the one stroke than the other, adjustable external resistances may be used, strengthening one magnetic field and weakening the other to suit the circumstances of the work; and in many cases diminishing the wear and tear on the machine due to the shock of the return stroke. But the loss of current caused by this arrangement may be obviated, by winding one or the other of the two coils in sections connected up in parallel,* so increasing the ampère-turns at either end to any desirable extent.

NOTE.—The author expresses to the following students in the Department of Electrical Engineering his many obligations for valuable assistance: Mr. F. McS. Thomas, for constructing the solenoid mechanism; Messrs. T. M. Brown, W. R. Molinard and J. B. Scott, for arranging the dynamo details; and Messrs. L. M. Aspinwall, H. W. Frye, H. Pattison, A. J. Rowland and R. I. Todd, for observations.

CORRESPONDENCE.

THE DYKE AT THE HEAD OF PEA PATCH ISLAND, DELAWARE RIVER.

To the Committee on Publications:

GENTLEMEN: With reference to the admirable lecture of Capt. F. A. Mahan, Corps of Engineers U. S. A., on "Philadelphia as a Seaport," published in your last issue, it may interest some of your readers to know that the dyke to be constructed at the head of Pea Patch Island above Fort Delaware, for the improvement of Bulkhead Shoal, is a departure from the dyke proposed for the same locality by the Board of Engineers of 1885, approved by the Chief of Engineers United States Army; and that the new dyke was proposed by the writer in April, 1890, while yet in the United States Engineer Office at Philadelphia.

The dyke proposed by the Board of Engineers was a curved dyke, presenting its concavity toward the Jersey shore, and its location with reference to the currents was, in the opinion of the writer, not well calculated to produce the desired effect upon the shoal.

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* The use of regulating resistances and of multiple-sectioned coils in this mechanism are set forth in the United States Patent (Van Depoele), No 422,855, of March 4, 1890.

When Major C. W. Raymond, Corps of Engineers, took charge of the office in Philadelphia, in the spring of 1890, the assistant engineer, Mr. L. Y. Schermerhorn, brought before the writer the question of the improvement of Bulkhead Shoal, and in the discussion which ensued, the writer, with the light of his several years of observations and studies of the behavior of tidal currents on the Delaware River, in which he had been exclusively engaged, demonstrated the inefficiency of the dyke proposed by the Board and expounded the project of the new dyke, known as the west dyke, which Capt. Mahan ably and succinctly describes in his lecture as a dyke "to begin at the head of Pea Patch Island and extend up stream. Its middle and lower parts are intended to train the flood currents on the bar and prevent the westward movement of the flood channel, while the upper is to catch part of the ebb down the Delaware channel."

This dyke is also a curved dyke, but instead of presenting its concavity toward the Jersey shore, presents it toward the Delaware shore with the important features described by Capt. Mahan.

As soon as the assistant engineer, Mr. Schermerhorn, became converted to the new dyke, he took it upon himself to convert Major Raymond, who at first opposed it and finally became enamored of it to the extent of meeting the natural opposition of the Board of Engineers. It was at this time that the writer was suddenly notified that his services for reasons of economy would have to be dispensed with, and was given about one month and a half to leave. He left, however, one month sooner, with loss of his salary and not a word on official record about the whole matter.

Mr. Raymond succeeded, in his turn, in convincing the Board of Engineers of the superiority and merits of the new dyke he had espoused, and received the approval of his chief.

There has been before this no occasion given to put the above facts on record, and the writer is glad to do it now before the new dyke is pronounced either a success or failure.

L. d'AURIA.

BOOK NOTICES.

Electricity and its Recent Applications. Edward Trevert. Bubier Publishing Company, Lynn, Mass.

This is the fifth book upon electrical subjects by this author, and as his style is so well known it need not be referred to again. A great many books have recently appeared, purporting to disclose the mysteries of electrical phenomena to the youthful and ignorant, and to tell them how to make and use dynamos, motors, batteries and sundry apparatus. Doubtless such books have a field, and this latest one is simply another addition to the number. It is very easy reading, not requiring much thought, except where it is impossible for the subject-matter to be made intelligible to beginners anyway.

and in fact it does not attempt to elucidate *principles* at all, but to explain ephemeral apparatus so that, without much effort, the reader can get a smattering familiarity with some of the most prominent applications of electricity, and be told how to make some pieces of apparatus and perform some experiments.

The book opens with the misleading statement that "electricity and magnetism are very closely related, electricity producing magnetism, and magnetism producing electricity." Being coëxistent they can hardly be said to produce each other. A few pages of dissertation follow upon some experiments with magnets and iron filings, although the reader is left almost entirely in the dark as to the principles involved, and yet without further elucidation he is required to read under the chapter "Field Magnets" about "magnetic fields," "electro-magnets," "to vary the intensity of magnets," etc., and is expected to understand what he is reading, and to understand the various forms of field magnets which are shown with but slight reference; after which some attempted explanations are given about the design of magnets and armatures! How beginners are to understand the design of magnets and armatures without having been given the first principles, it is difficult to perceive. So also in the first chapter, after a few remarks about the time-honored amber experiment, the reader is at once confronted with the complicated Holtz and Toeppler machines, which are again erroneously called "frictional machines" and which scarcely one reader in 1,000 will understand. Yet six pages are devoted to it in this book for amateurs and beginners.

The second chapter is devoted to "Voltaic Batteries" and with but a feeble introductory explanation of the action of cells, some of the more modern cells are explained and directions given for constructing them and for setting them up, although most of this is put into the chapter on "Gas Lighting Apparatus."

In the brief discussion of "storage batteries" the reader is impressed with "the possibility of *storing electricity !!*" And no attempt is made to set him right. The terms "current," "resistance," "ampères," "ohms," "volts," etc., are used freely in this chapter though no explanation is given of what these terms mean; some calculations of the number of cells required to run a lamp are given, though the reader has not even been told of the relation existing between the quantities involved.

And so all through the book there occur some explanations of apparatus, but no attempt at a logical presentation of fundamental principles, but on the contrary many misleading statements and obsolete definitions.

The volume closes with an "illustrated dictionary of electrical terms and phrases" of twelve pages and seven illustrations; many of the definitions contained in it are unfortunately as unintelligible and perplexing as the following: "Potential: Power to do work;" "Condenser: An apparatus for collecting and holding electricity;" "Electrode: A pole of a battery;" "Pole: The pole of a battery is one of its terminals;" "Terminal: The point at which the electricity enters or leaves an electrical apparatus," thereby informing the reader who wishes to know what an electrode is, that it is "the point at which electricity enters or leaves an electrical apparatus." Yet in the preface is found the statement that "there seems to be a demand for more information * * * particularly among amateurs and students. For this reason I add this one to the list * * * and confined myself to facts, rather than theory."!!

Many excellent pictures of some modern commercial apparatus, mostly from trade publications, are shown, which serve their purpose well in interesting the amateur reader who does not see the electrical journals, but many of the illustrations are merely photo-engravings of extremely bad sketches, for instance those on pp. 178, 180, 185, and others, and it is surprising that such bad ones were ever permitted to appear in print.

There is no index to the book and no pages given in the contents, neither is there the slightest intimation at the top of the page, of the subject of the chapter, so that the reader is obliged to look from page to page should he wish to find a certain chapter, or look up a certain subject. It is most extraordinary how careless and regardless of the convenience of readers some authors and publishers are in matters of this kind.

For anyone wishing to read a little descriptive matter about batteries, dynamos, lamps, etc., and how to put up and operate electric bells and gas-lighting apparatus, and to make dynamos or motors, this book may prove useful, but for those seeking explanation of principles, and of the terms and quantities involved, it will be utterly useless.

It is to be regretted that so many so-called "practical" or "amateur" treatises make the serious mistake of not adopting the very first essential principles of education in the methods of presenting a subject, dealing as they purpose doing, with amateurs and persons of little education. They are not to be criticised for endeavoring to enlighten the unenlightened; that is a worthy object, but they do not put their readers on any solid foundation, but turn them loose among kaleidoscopic views of machines and appliances and alluring temptations of making dynamos, motors, etc., yielding to which generally ends in disappointment, and also allow them to form the most erroneous notions about the simplest phenomena. H. S. H.

Duhem, chargé d'un cours complémentaire de Physique mathématique et de Cristallographie à la Faculté des Sciences de Lille. *Leçons sur l'Électricité et le Magnétisme.* 3 volumes grand in-8, avec figures dans le texte, se vendant séparément. Paris: Gauthier-Villars et fils. 1891. Tome I: Conducteurs à l'état permanent. 1891. 16 fr.

The aim of the author of this work, as stated in the preface, has been to assemble in definite form and logical sequence the results of almost a century of mathematical investigation of the laws of electricity and magnetism, carried on by the leading specialists of all countries.

The first part of the present volume is devoted to a study of the fundamental laws of the electrical equilibrium and of the best mathematical methods of dealing with the phenomena of electro statics. Beginning with the laws of Dufay and Coulomb, the properties of potential at points external and internal to a given system are taken up, together with the laws governing surface charges in masses of different size and form.

Part 2 contains much of value regarding the distribution of electricity in conducting bodies, with ample mathematical treatment of the laws of equilibrium. In Chapter 5 the Dirichlet principle and the so-called problems of Le jeune Dirichlet are given interesting treatment. It is shown that the problems are really but another form of a problem proposed by Green, in 1828. In 1839, Gauss also stated an equivalent problem, and in 1845, Sir W. Thomson stated still another form of the problem, showing by a method analogous to that of Gauss that it was always capable of one solution. The scope of the Dirichlet principle is shown and the weak points of Le jeune Dirichlet's demonstration indicated in a forcible manner. In logical order we find the laws of the natural distribution of electricity on a conducting body, with an exposition of the elegant method of M. G. Robin for determining the same.

The third part consists of experimental studies of electrical distribution, examples of various cases of electrical influence and special classes of condensers being given with their complete treatment. Green's problem with solutions by his own method and that of Gauss, with Dirichlet's application, are taken up in Chapter 5 along with the theorems of Faraday and their applications to questions of electrical influence.

Part 4 takes up thermodynamics, showing certain theorems forming a bond between this branch and mechanics. Book 10 treats of the fundamental laws of electrical equilibrium in metallic conductors, *i. e.*, in a system composed of conductors in which the electrical distribution can be modified without modifying the physical or chemical state of any one of them. Chapter 4 takes up the law of Ohm, and is followed by the proof of this law in conductors of special forms. The interesting geometrical treatment given shows as its result the absolute solution of the movement of electric currents in conductors of the form of a plate, knife section, curved knife section, etc. The law of Joule is stated with a great number of hypotheses in connection therewith. The electrical equilibrium in a conductor composed of different metals is shown as affected by the laws of thermodynamics. The Peltier effect is studied in Chapter 8, and in the two remaining chapters the conditions under which thermo-electric currents are produced are considered together with the Thomson effect.

The final book of the volume is given up to electrolytes with the laws of Faraday. The distinction between chemical and voltaic heat is shown with the relation established by M. von Helmholtz between the two and the electromotive force of a hydro-electric battery.

The work, as a whole, cannot be regarded as a compendium of theories, but rather as a treatise on the theories of electricity and magnetism. The author realizes the demand that exists in this as in other branches of the science, namely, for text books which shall embrace under one cover the results of the study and experiment of the leading philosophers of all countries, and to meet it has collected all available matter from reviews, scientific papers and works published in all languages. Having arranged his subjects in logical order he has crystallized upon this framework the ideas that seemed most prolific and desirable.

The author has made a novel and daring departure for the usual methods of treating the theoretical study of the phenomena of the science. He borrows from "Mechanics" and "Thermodynamics" certain well-proven principles and theorems, and about these groups all the important and prolific theories of electricity. While these principles, as ordinarily evolved, are sufficient to meet the problems of physics, it is necessary to surround them by so many restrictions, conditions and hypotheses to meet the complex cases offered by electric theories, that the undertaking is a serious one.

The writer has therefore chosen a new course, and instead of first showing, as would logically be necessary, the manner in which these principles may be used to classify the theories to be studied, he shows the bond as the study proceeds.

The definitions given are original and clear without being lengthy. The nomenclature adopted is supported by good reasons, and is not to suit the author's convenience or fancy. The mathematical methods are satisfactory, complete and logical.

The treatment of metallic conductors, both homogeneous and heterogeneous, with the application of the laws of the thermodynamics to these conductors, is very complete, and undoubtedly the most extensive and thorough up to date.

The chapters upon electrolytes are rather brief, although they cover many useful propositions relating to open and closed circuit batteries both polarizable and non-polarizable. If one considers, however, to what extent they would lead were the same methods employed as for metallic conductors, this is not surprising.

No attempt is made to introduce any of the usual matter relating to the measurement of current strength, etc., nor anything regarding the instruments used. The work is not, in fact, calculated for the use of the practical or experimental electrical engineer as a manual, but rather as a treatise which shall show the bonds uniting the various electrical theories, and the scope and extent of these theories. C. J. R.

A Manual of Mining. By M. C. Ihlseng, C.E., E.M., Ph.D. Pp. 428. 8vo. Cloth, $4. New York: John Wiley & Sons.

This is, we believe, the first work of the kind published in this country, and as the literature of mining in the English language is singularly scant, it makes a most welcome addition.

As a text-book on the art of mining it does not compare favorably with the German works of Serlo, Köhler, or even with the French of Callon.

The author has unfortunately attempted to cover too much in a small volume, and as a consequence many of the most important parts of his subject are treated in a superficial manner; indeed, this is so far true that unless the reader has had some experience in mining, the book would not be entirely intelligible. The book is unevenly written, some of the chapters being better than others. Those on ventilation, it should be said, are particularly good. The author states in the preface "the work is designed as an elementary treatise for the use of those desiring a reference book." The book does not conform to this description, for the reader is met at every turn with terms and expressions which would require considerable previous knowledge of mining on his part to be intelligible.

On the whole the book is a good one. It contains much valuable practical information and, therefore, forms a valuable contribution to the literature of the subject. It is to be regretted that it is not better written; the author's style is often involved, rendering his meaning obscure; his English lacks clearness, and the interjection of the slang of the mining districts of our far West, cannot be considered as good form in a work of this character.

F. L. G.

PHOTOGRAPHIC NOVELTIES.

[*Abstract of remarks of Mr. John Carbutt, made at the stated meeting of the Institute, Feb. 17, 1892.*]

Mr. John Carbutt exhibited several large and beautiful photographs of scenery on the Pennsylvania Railroad, taken on his celluloid orthochromatic films, and spoke of the advance in use of that material, as follows:

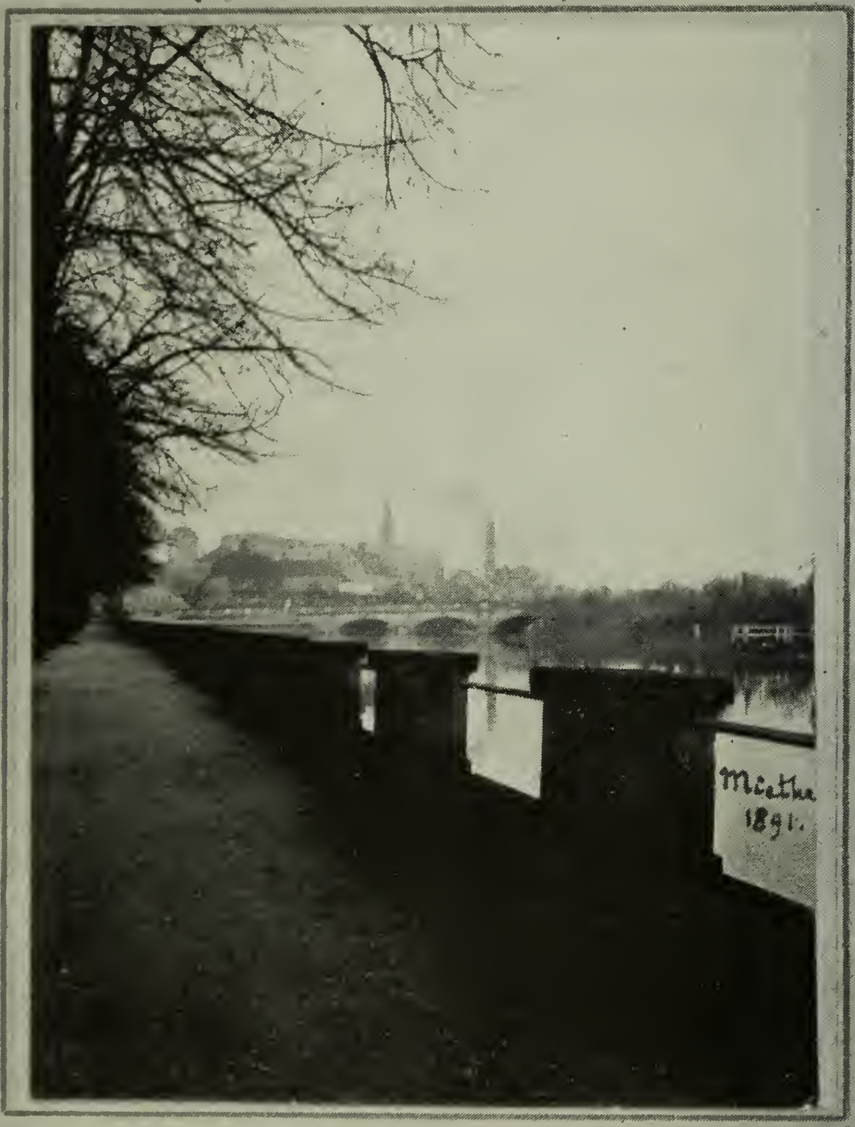
Mr. President and Members:

It will be remembered by members of the Institute that some four years since I read a paper on celluloid as the new substitute for glass in photography, and that, although the sheets of celluloid measured 20 x 48 inches, the largest negative made at that time was 8 x 10 inches. Since that time the use of that material both by amateur and professional photographers has greatly increased, as also the size of negatives made, especially by the professional photographers, notably Mr. W. H. Rau, of this city, who, during the past summer, has made negatives of views on the line of the Pennsylvania Railroad of the size 18 x 22 inches, used flat in the regular plate-holder, and 18 x 48 inches used in the panoramic camera, but bent to a half-circle, as shown by the sketch on the blackboard.

Here is one of the flexible holders carrying the 18 x 48 celluloid film, which as you see can be bent to a half-circle, which form it occupies when attached to the camera, the back of which forms a half-circle, the front being flat and flexible, allowing the lens to be rotated from side to side while making the exposure. The lens used has a focus of fifteen inches, and the negative includes an angle of 165°; whereas if it was possible for a lens of fifteen inches focus to cover a flat surface of forty-eight inches, the angle would only be 110°.

The photographs here for your examination fully illustrate how perfectly the celluloid answers the purpose to hold the sensitive film, doing away with both weight and risk of breakage to which glass is subject. One of our leading amateurs, Dr. Chas. L. Mitchell, made over 500 8 x 10 nega-

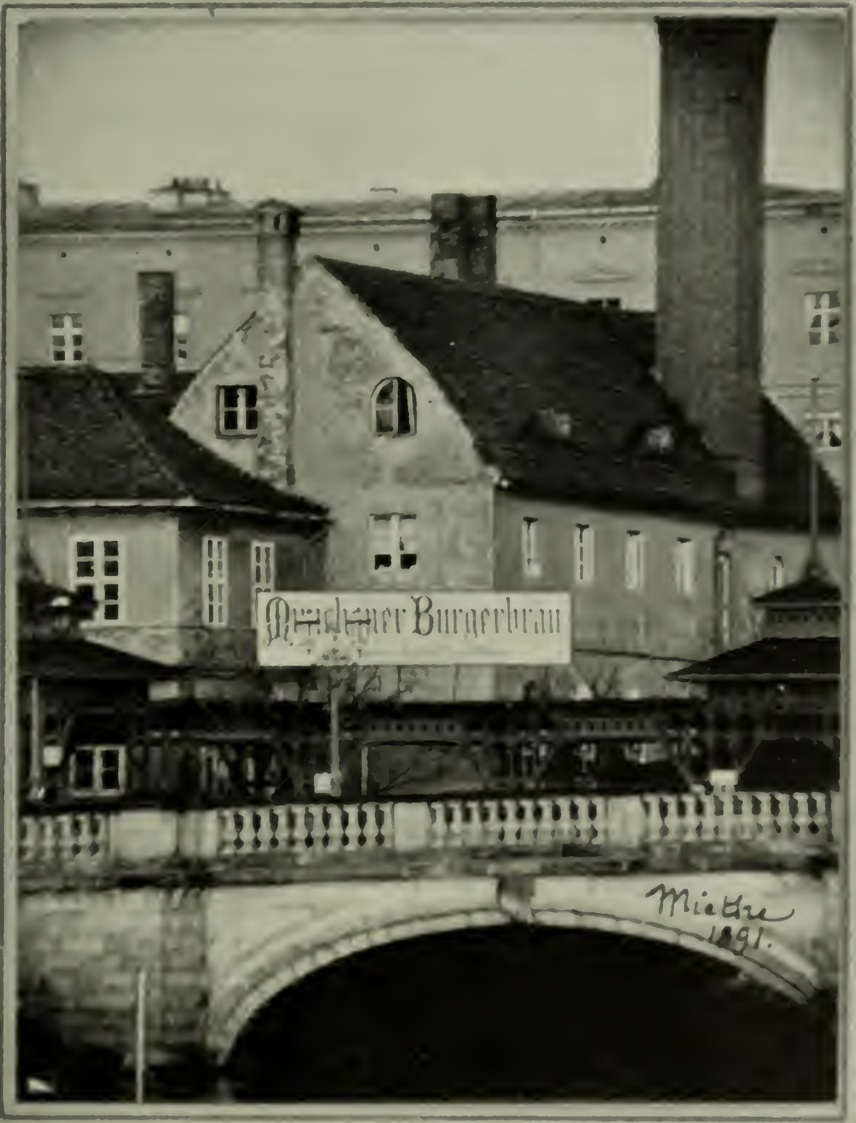
From the same standpoint



taken from a distance of 350 m. with an ordinary Dr Miethe's symmetrical lens, smallest stop, Expos. 1,5 sec.

(Carbutt.)

From the same standpoint



taken from a distance of 350 m with Dr Miethe's new telephotographic lens. Camera length: 28 cm.
Expos: 05 Sec

tives of Norway the past summer on orthochromatic films, and the use of celluloid films is greatly on the increase by travellers, tourists, and the professional photographer.

The second advance in photography to which I desire to call your attention, relates to the production of a lens capable of giving a greatly magnified image of an object at a great distance from the camera, and is called the photo-tele objective. Dr. Miethe, of Berlin, and Mr. T. R. Dallmyer, of London, both claim originality in the construction of the lens, but it appears both were anticipated several years, for in the *British Journal of Photography*, of January 29th, this year, Dr. Hugo Schroeder gives dates and drawings of a photo-tele objective constructed by him in 1869–70, and I have in my possession the amplifier constructed in 1869, by the late Mr. Joseph Zentmayer, for Prof. Henry Morton, and attached to the telescope used in taking photographs of the eclipse of 1869. The sun's direct image was thus made about two and one-half inches in diameter. To Dr. Miethe, however, is due the credit of first constructing an objective suited to the photographer's use, and I will now show on the screen, first a view made with the ordinary objective, and then one by the new. Now I will throw on the screen a slide of both pictures; you readily see the immense difference in the size of the same object, both cameras being placed side by side, and of about same focal length. You will observe the sign on the building, taken by the Miethe objective is about ten times larger than the one with regular photo lens.

[By courtesy of the *American Journal of Photography*, the *Journal* is enabled to exhibit to its readers the accompanying handsome Ives' process plate of the pictures referred to by Mr. Carbutt.—W.]

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 16, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 16, 1892.

Mr. JOS. M. WILSON, President, in the chair.

Present, 103 members and seven visitors.

Additions to membership since last report, nine.

The Secretary reported the resignations of Messrs. Wm. Harkness, Jr., and John F. Haskins from the Committee on Science and the Arts. The vacancies were filled by the election of Mr. Arthur Kitson for the unexpired term of Mr. Harkness, and Mr. J. C. Trautwine, Jr., for the unexpired term of Mr. Haskins.

Mr. F. Lynwood Garrison, who had been named as the Institute's representative, to witness the recent tests of armor plate made at the Indian Head proving grounds, under the direction of the Ordnance Department of the Navy, gave a description of the character of these tests, and of the conclusions to be drawn therefrom, illustrating his remarks by the exhibition of a series of lantern slides. (A report on this subject will shortly appear in the *Journal.*)

Mr. Elmer G. Willyoung described an extensive and handsome series of philosophical and engineering instruments made by Queen & Co., of Philadelphia, in the construction of which aluminum is employed largely. Mr. Willyoung explained that as the result of long-continued experiments, these manufacturers had succeeded in overcoming most of the difficulties in the way of working and manipulating aluminum. The exhibit was much admired, and the speaker's remarks evoked a number of inquiries.

Mr. H. W. Bartol described and illustrated by a series of lantern slides the construction of the Buda Pesth electric railway, and gave an account of its principal features—technical and economic. (A description of this railway appears in the *Journal* for February, 1892.)

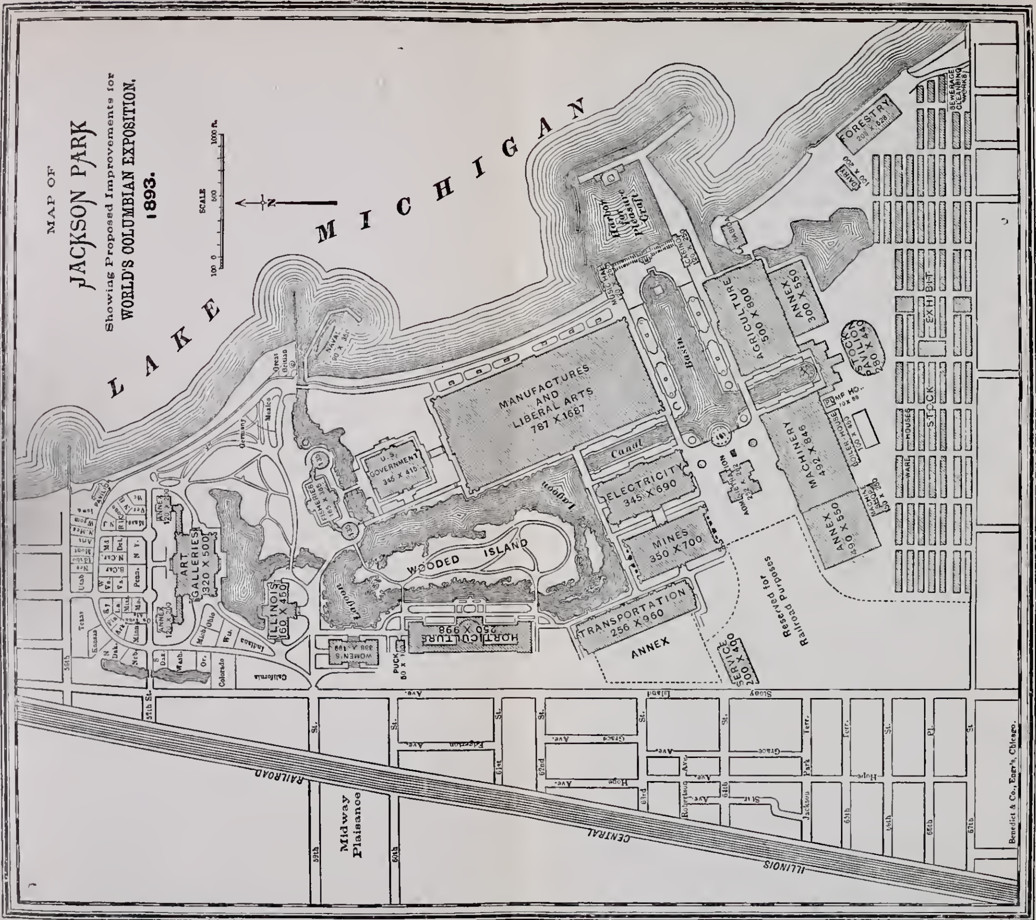
Mr. John H. Cooper presented an abstract of the report of the Committee on Science and the Arts, on the Batchellor compound locomotive, manufactured by the Rhode Island Locomotive Works, of Providence, R. I., with suitable illustrations.

Mr. John Carbutt presented some remarks in relation to the admirable results achieved by Mr. Fred. E. Ives, in the field of color photography, which, in his judgment, so far as practical results were concerned, were far in advance of anything that had as yet been accomplished elsewhere. He urged that it was eminently fitting for the Institute to recognize the value of the work of one of its own members, and moved that the subject of Mr. Ives' investigations and results in the field of color photography be referred to the Committee on Science and the Arts for investigation and appropriate recognition. The motion was carried.

The Secretary offered the following resolution, which was adopted unanimously :

Resolved, That the grateful thanks of the Institute be and are hereby tendered to Mr. Fred. E. Ives, in appreciation of the zealous and gratuitous services rendered by him during a series of years in superintending the work of lantern illustrations at the meetings and lectures, which he has done with exceptional skill and ability.

Adjourned. WM. H. WAHL, *Secretary.*


MAP OF
JACKSON PARK
Showing Proposed Improvements for
WORLD'S COLUMBIAN EXPOSITION.
1893.
SCALE
100 0 500 1000 ft.
N
LAKE MICHIGAN
Harbor for Pleasure Craft
FORESTRY 208 X 528
SEWERAGE CLEANING WORKS
DAIRY 100 X 200
CASINO 120 X 250
MUSIC HALL
AGRICULTURE 500 X 800
ANNEX 300 X 550
STOCK PAVILION 280 X 440
STOCK EXHIBIT
WARE HOUSES
Basin
NAVAL 90 X 350
MANUFACTURES AND LIBERAL ARTS 787 X 1687
U.S. GOVERNMENT 345 X 415
FISHERIES 165 X 365
Canal
ELECTRICITY 345 X 690
ADMINISTRATION 262 X 262
MACHINERY 492 X 846
BOILER-HOUSE
PUMP HO.
MACHINE SHOPS
ANNEX 490 X 550
MINES 350 X 700
Lagoon
WOODED ISLAND
ART GALLERIES 320 X 500
ANNEX
ILLINOIS 160 X 450
HORTICULTURE 250 X 998
WOMEN'S 388 X 199
PUCK
TRANSPORTATION 256 X 960
ANNEX
SERVICE 200 X 400
Reserved for Railroad Purposes
Germany
Mexico
Texas
Kansas
Utah
Idaho
Iowa
Wash.
Colorado
California
Indiana
Wis.
Minn.
Ohio
Mich.
Penn.
N. Y.
Neb.
S. Dak.
N. Dak.
Ark.
Ky.
Va.
W. Va.
Mass.
Me.
Conn.
Del.
N. Car.
S. Car.
Md.
R.I.
N. J.
Vt.
Mont.
Ore.
Midway Plaisance
ILLINOIS CENTRAL RAILROAD
56th
57th St.
59th St.
60th St.
61st St.
62nd St.
63rd St.
64th
65th
66th
67th St.
Stony Island Ave.
Edgerton Ave.
Grace Ave.
Hope Ave.
Star Ave.
Robertson Ave.
Jackson Park Terr.
Benedict & Co., Engr's, Chicago.

JOURNAL

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VOL. CXXXIII. MAY, 1892. NO. 5

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE DEVELOPMENT OF AMERICAN ARMOR-PLATE.

BY F. LYNWOOD GARRISON.

PREFATORY NOTE.

[It was the original intention of the author to contribute to the Franklin Institute the results of the recent armor-plate trials at Indian Head, in the form of a report. Owing, however, to the unavoidable delay in publishing the contribution, and to the fact that an excellent report of these trials has been published by the Chief of the Bureau of Ordnance of the Navy, such a report would appear unnecessary.

His aim has been, therefore, to prepare a paper giving a brief sketch of the development of armor-plate, together with the more important details of the official report.

The paper has been prepared from the standpoint of the metallurgist, rather than that of the military engineer.

In the works of Very and Orde-Browne we have a complete and excellent history of the development and use of heavy armor-plates for naval and military purposes, but in these works the metallurgical side is but lightly touched upon.

Of course, much might be written upon the methods and appliances used in the manufacture of armor-plate, but such would seem more properly to belong to the province of metallurgy, than to a short paper on the present status of armor-plate in the United States. At the present time great interest is centred upon the use of the complex steel alloys and the methods used to harden them, and it is to these subjects more particularly that the author would call attention.

The detailed methods of producing such alloys as well as the several methods for quenching and tempering armor-plate are naturally kept secret by the steel manufacture.

The results of such operations are, of course, made public at the trials, and the possible deductions to be made therefrom are patent to every observing and thinking engineer.

The fact that the author has had exceptionally good opportunities to make such observations, he feels to be a sufficient excuse for publishing his views in the following paper.]

Sir Thomas Brassey, in his work on *The British Navy*, in speaking of armor and armor experiments,* says: "The defensive armor with which it has been customary of late to protect the heavy ships of modern fleets, may be considered with reference to its thickness, the material of which it is made and the method employed in its manufacture." Though ships' armor has been rarely subjected to the experience of real war, many questions referring to resisting power of the plates composing it have long been experimentally settled. "The general question is entering on a new stage; and there is now a *prima facie* case for inquiry, whether the increased power of armor-piercing guns and the augmented thickness of plates, as well as the introduction of new material into its composition, have not created a set of conditions which no longer support previously received theories of penetration and resistance."

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* London, 1882, vol. ii, p. 3.

These remarks were made in 1882, and now, in 1892, we find that with the introduction of nickel-steel and other alloyed* steels and with special processes for increasing the superficial hardness of armor-plates, the prediction is amply sustained.

One cannot but be impressed with the fact that with nearly every advance in the naval arts, the demands placed upon the metallurgist increase more and more; surely now, more than ever before, the arts of war must advance hand in hand with the arts of peace.

It seems eminently a prerogative of an institution like the Franklin Institute to take an active interest in the efforts which our Government is making to create a modern navy; surely there is no body of technical men in this country that can better appreciate such work or give it more aid.

In the armor-plates tried at Indian Head, October 31st and November 14th, the author ventures to say we have the most complicated metallurgical products ever dealt with by man. How little we know of that mysterious alloy called steel, how much less when it is further complicated by additions of nickel, copper, etc.!

In order that the author's remarks may be more intelligible to persons in civil life, he has deemed it proper to give a short sketch of the history of protecting ships of war by metallic armor. The subject is much more extensive than generally supposed, and its present advanced stage has only been reached by slow degrees and with a vast expenditure of money.

Although a number of schemes for the use of iron plates to protect batteries and ships were devised between the years 1812 and 1855,* it was not until the Crimean war that any practical results were obtained.

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* I use the word alloyed here in want of a better term; any steel is an alloy of iron and other elements, but it has only been with the introduction of this new class of steels that it has been necessary to use a compound word to indicate their distinctive characteristics. G.

During the action at Kinburn the French floating batteries, protected by four and one-half inch iron plates on seventeen inches of wood backing, were repeatedly hulled by the Russian guns, with no other result than the denting of the plates to the extent of one and one-half inches. In 1857, four-inch iron plates and two-inch steel plates, secured by bolts to two feet of oak, were tested at Woolwich with sixty-eight-pounders with unsatisfactory results. At 400 yards the plates were badly broken up by both cast and wrought shot.†

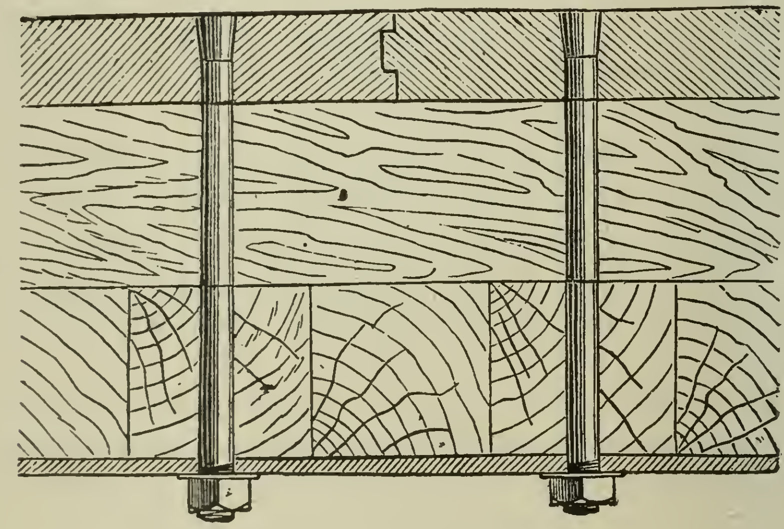

FIG. 1.—*Warrior* target.

In 1861, a target representing a section of the side of the new iron-clad ship *Warrior* (*Fig. 1*), was tried at Shoeburyness with 68-, 100- and 120-pounders, with the result that the plates were more or less cracked, but the ribs and inner skin uninjured. The *Warrior* target was constructed of four and one-half-inch solid iron plates, tongued-and-grooved as shown in *Fig. 1*. The design of the bolts should be noted, as they were vastly better than the system used on some of the earlier American iron-clads.

Ericsson's first battery, the famous *Monitor*, was protected on the upper hull by six thicknesses of one-inch iron plates with one-half-inch inner skin; the deck by two layers of one-inch iron, and the turret by eight thicknesses of one-inch iron bolted one over the other with overlapping joints. The system of bolting can be fairly well understood from *Fig. 2*,* which was reproduced from a photograph taken shortly after the action with the *Merrimac*. In 1863, a target representing a section of the side of the iron-clad frigate *Bellerophon*, was tried in England. The armor (*Fig. 3*) consisted of six-inch rolled iron plates (not tongued-and-grooved as in the *Warrior* target), bolted to an oak frame with two and one-half and two and three-fourths-inch bolts. Each frame of the target was made of an angle iron 10 x 3½ x ½ inch, and two of 3½ x 3½ x ⅝ inch, riveted together. To the frame thus formed a skin of two thicknesses of three-fourths-inch iron was riveted. On the outside of the skin four horizontal angle-iron stringers were attached, two under the upper armor-plate 9½ x 3½ x ½ inch, the broad flange being square to the skin, and not reaching out to the armor by half an inch. The other two are placed behind the lower plate 10 x 3½ x ½ inch. The breadth of the broader flange being

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* See Holley's *Ordnance and Armor*, pp. 623–627.

† *Ibid.*, p. 630.

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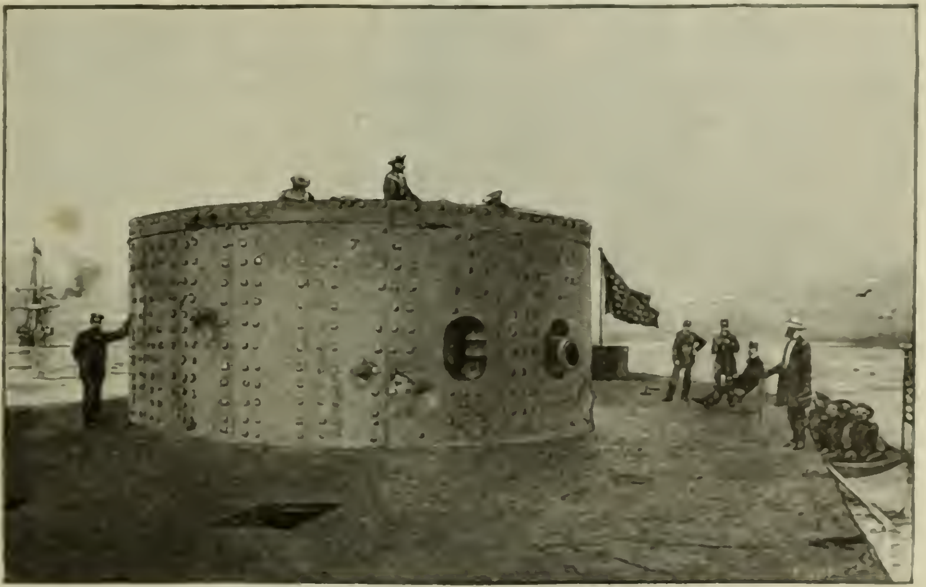

Fig. 2.—*Monitor* after action with *Merrimac*.

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* The author is indebted to the publishers of *The Century Magazine*, of New York, for the loan of this cut.

the same as the thickness of the backing, it reaches out to and comes in contact with the armor.*

This system made a very material improvement in the structural strength as well as a great addition to its power of resisting projectiles. From this period on, the thickness of iron armor and the wood backing rapidly increased; it seems to have reached its maximum in 1876 in the twenty-two inch iron plates tried at Spezzia during the autumn of that year.

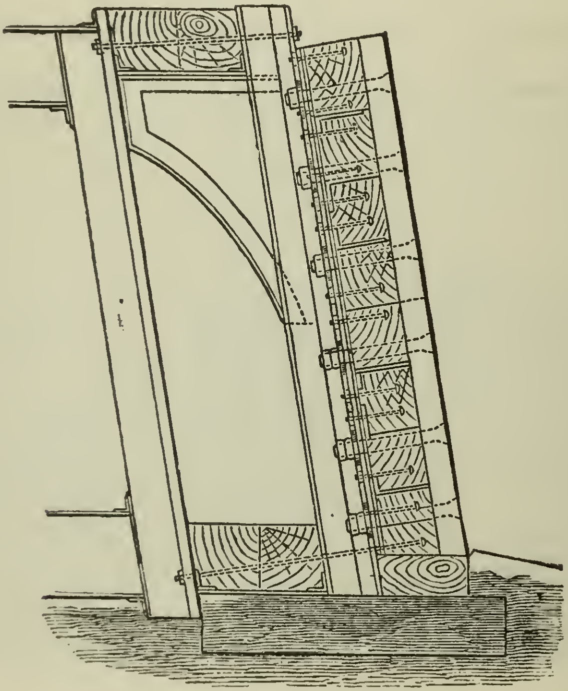

FIG. 3.—*Bellerophon* target.

Up to about 1879, wrought iron in various shapes was almost exclusively used for armor. Browne states that the chief value of wrought-iron plates is due to the fact that they do not transmit the shock to the bolts and adjacent parts of the structure. The blow is absorbed locally. They do not crack much if supported by proper backing, and may be penetrated with comparative ease.

In 1868, what was known as the Hughes hollow stringer (*Fig. 4*) was tried in the construction of the famous Millwall shield. The use of these hollow stringers was estimated by the Russian authorities to be equal to two inches of iron in increasing the defensive capacity. The arrangement of these stringers is shown in *Fig. 4;* they are placed horizontally and riveted to the side of the vessel, the hollow portion being filled with oak or teak.*

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* Holley, *Ordnance and Armor*, p. 761.

The following analyses of Russian and English iron armor-plates have been published by the Russian authorities.†

Russian Plates.

			I.	*II.*	*III.*
Carbon,	compound,	=	0·07	0·06	0·07
	graphitic,	=	0·02	—	0·019
Silicon,		=	0·12	0·20	0·15
Manganese,		=	0·09	0·17	0·03
Phosphorus,		=	0·12	0·36	0·04
Sulphur,		=	0·02	0·038	trace
Arsenic,		=	0·106	0·05	trace
Copper,		=	0·02	—	0·07

English Plates.

		I.	*II.*	*III.*
Carbon,	=	0·04	0·07	0·05
Silicon,	=	0·117	0·20	—
Manganese,	=	0·09	0·10	0·21
Phosphorus,	=	0·165	0·17	0·23
Sulphur,	=	0·01	trace	—

It might be well in this place briefly to consider what efforts have been made to use *cast iron* for defensive purposes.

Chilled cast iron is one of the hardest substances known in the arts, but what iron gains in hardness when in this form it loses in other qualities such as elasticity, ductility, etc. In order to possess a maximum of ballistic resistance an armor-plate must be not only very hard, but also elastic and ductile; these fundamental conditions have been thoroughly demonstrated by several trials of chilled cast-iron armor. Two firms in Europe have manufactured armor of this kind to a considerable extent; Gruson, of Buckau, near Magdeburg, Prussia, and the St. Chamond Company, in France. During the year 1884, a number of armor-plates of chilled cast iron made by Gruson were tried at Buckau. Krupp steel projectiles were used with guns of various calibres. The results of these trials appear to have been considered satisfactory at the time, as were also the similar trials of St. Chamond during April, 1884.*

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* Hamersley's *Naval Encyclopædia*, 1884, p. 47.

† *Stahl und Eisen*, vol. v, p. 69, *Journal of the Iron and Steel Institute*, No. 1, 1886, pp. 316, 317.

The result of trials several years later, however, led to both of these firms abandoning cast iron for armor-plate.

It appears from the total results of the trials, that for land defences (glacis armor chiefly), where the conditions were such that the angle of incidence of the projectile was not great, chilled cast-iron plates made a good defence. In almost every case the projectiles were broken up.

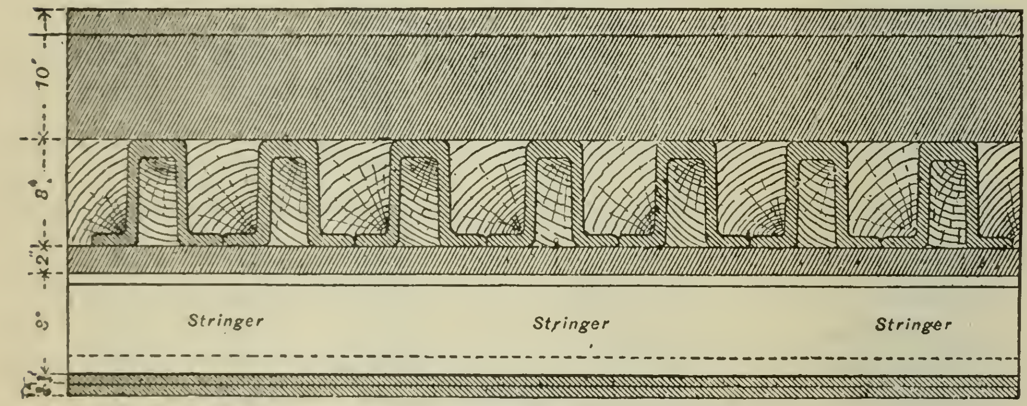

FIG. 4.—Hughes hollow stringer.

The penetration was very slight, the surface at the points of impact being chipped off, and, as would be expected, the general destructive effect upon the shield was to crack it in various directions.

When iron is in a crystalline state its tendency to crack under the impact of a projectile is intensified when the latter strikes at a glancing angle, for under these conditions a second blow is delivered by the base of the projectile whilst the molecules of the iron are yet in violent vibration, caused by the impact of the point or ogival.

On the other hand, these plates can be made cheaply and of great thickness for land defences, and owing to their hardness, rigidity and the rapidity with which they transmit shocks throughout their entire mass, they must be broken up bodily to be destroyed.

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* *Engineering*, October 17, 1884, p. 374.

Although this system of armor cannot be considered to have been entirely successful in practice, its peculiarities both as regards construction and the results obtained, deserve more than passing notice.

Gruson's theory appeared to be that as cast iron could be moulded into any desired shape, plates or blocks with a curved profile could be used, which, whilst to a certain extent gaining in efficiency through the power of deflection, gained more by giving to the chilled crystallization a direction such as would put the body of the metal in the best condition for resistance to impact, and give mutual support to the parts of a plate even when the latter was fractured.*

His turrets were made ellipsoidal in shape, so as to make all parts mutually supporting. The ends of each block were slightly hollowed, so that when put in position zinc solder could run into the cavity thus formed by the close-fitting adjacent ends of the blocks, securing them together and thus avoiding all bolts or fastenings of any other description.

What mixture of pig irons Gruson uses to make these castings are not known outside of his works. It produces, however, peculiarly good results.

The fracture is a clear steely-white from the outer surface to about one-quarter of the depth of the casting, changing very gradually to a mottle for one-third farther, the remainder being a fine close-grained dark gray iron. There is no line of demarcation whatever between the chill and the soft iron, the one shading off almost imperceptibly into the other. The structure of the iron throughout appears as fine and close as in Whitworth's fluid-compressed steel, and entirely free from flaws.†

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* Very, p. 532, *Development of Armor for Naval Use. Proceedings of the U. S. Naval Inst.*, vol. ix. No. 3 [1883].

† Very, p. 533.

According to Barnaby,* satisfactory results were not obtained with the use of steel armor until the Spezzia trials of 1876. The plates then tested were 55 cm. (21·5 inches) thick, made at Creusot and such plates were subsequently used by the Italian Government to plate the *Dandolo* and *Duilio.* Three different systems of twenty-two inch armor were then subjected to strictly comparative tests, viz: English and French solid rolled iron plates; sandwiched plating of 10 x 11½ inch iron, interspaced with wood, and one Creusot solid steel plate. The projectiles from a 100-ton (seventeen inch) Armstrong gun completely perforated and broke into fragments the iron plates; it perforated all of the sandwiched plates but failed completely to penetrate the steel one.

When steel for armor was first introduced to any practical extent, it was thought by some authorities that such plates need only be cast, not forged or rolled, but simply quenched in oil and annealed, thus dispensing with all expensive forging operations. This system, however, was soon abandoned for compound or solid forged steel plates. The rivalry between these latter two systems has been keen and active for a number of years, although the solid steel plates made at Creusot have repeatedly shown themselves to be superior to any form of compound armor.

A few years ago, thinking the armor problem about definitely solved by the use of compound armor, the British Government formally adopted it. This led to the expenditure of large sums of money in developing its manufacture in England, which, though active at present, will undoubtedly be discontinued before long.

Before leaving the subject of iron armor, it will be of interest briefly to review some of the metallurgical difficulties overcome in its development. "Between 1854 and 1858 armor-plate manufacture was limited in thickness to four and one-half inches, and but little dependence could be placed in regularity of quality even with this low thickness. The welding was imperfect, the best composition of ores to produce desired results was not known, steely spots, burned metal, layers of scoria and scale, blow-holes and other imperfections were common and had to be accepted. At first the only rolls available for making armor were such as were used for boiler plates, and these were too light for the requirements. In consequence, the metal was shaped almost entirely under the hammer, which naturally would give results much more irregular than rolling. Time was required to design and erect the proper rolls, so that the real improvement in the condition of armor-plate cannot be said to have commenced much before 1859, and it is about this time that the first real increase in thickness of plates from four and one-half to four and three-fourths inches becomes noticeable."*

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* *Trans. of the Institution of Naval Architects*, 1879, p. 29.

In the manufacture of the plates for the first French and English iron-clads much difficulty was experienced.

The worst trouble appears to have arisen from the prevalence of steely spots in the plates, which broke up the tools used in finishing and boring. The inspection was necessarily given wide limits. There was no experience to serve as a guide in this respect, so the manufacture was only carefully watched to gain the necessary knowledge, and the plates were only limited in tests for reception to the indications of specimens. In France, test plates were made of several different mixtures of iron, and were tested for strength in the tensile machine and under the hammer. In this way a standard was established, and the armor was all made of the same mixture. In the process of welding up the packets, the fag-ends were cut off and worked separately. They were then given the pulling and hammer tests to show the fracture, and if they failed to come up to the standard specimen the whole batch of plates was condemned. This was a very crude method of testing armor for reception, but was unavoidable at the start.†

For the sake of convenience we may divide steel armor under three heads, viz: compound, steel and alloyed steel.

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* Very, p. 368.

† *Ibid.*, pp. 370, 371.

Compound Armor.—The process of manufacturing what is known as compound armor-plates was first patented in England by Alexander Wilson, of the Cyclops Works (Cammell & Co.), Sheffield, in 1876.*

In 1880, J. H. Ellis, of Sheffield, patented a somewhat similar process which has since been used by Brown & Co., of that place.†

The only difference between the two methods, as the author understands them, is that in the Wilson method a certain amount of low carbon steel ("ingot iron") is first cast on the hot wrought-iron back, and then a third layer of high carbon steel cast upon that, the wrought-iron plate being contained in a suitable cast-iron mould. By the Ellis method the low carbon ("ingot iron") steel plate forms part of the mould, the high carbon steel being cast in a space provided between the wrought-iron back and this plate.

Wilson specifies in his patent that the low carbon steel shall have a tensile strength of from 53,000 to 60,000 pounds per square inch, and that the high carbon steel shall contain from 1·25 to 1·5 per cent. carbon.

Ellis specifies for the low carbon plate 0·8 per cent. carbon and 0·8 per cent. manganese.

The principle in both methods appears to be, that the steel being at a much higher temperature than the iron plate, this excess of heat serves to bring its surface to a welding temperature. It is claimed the carbon in the steel carburizes the iron to a depth of from one-eighth to three-sixteenths of an inch, which, it is further claimed, constitutes an inseparable weld. As a matter of fact, however, the steel face is not always securely welded to the iron, and blisters of varying size occur at the joints. Even under the best conditions the steel face is liable to strip off the back, and where the projectiles penetrate, the holes are larger in the back than in front. This is strikingly illustrated in *Fig. 5*, which shows the Cammell compound plate at the Annapolis

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* See British Patents, 4,746-1876; 3,472-1877; 2,130-1882; 15,476-1886; 5,727-1887; 9,392-1888.

† See British Patents, 3,629-1880; 1,051-1882.

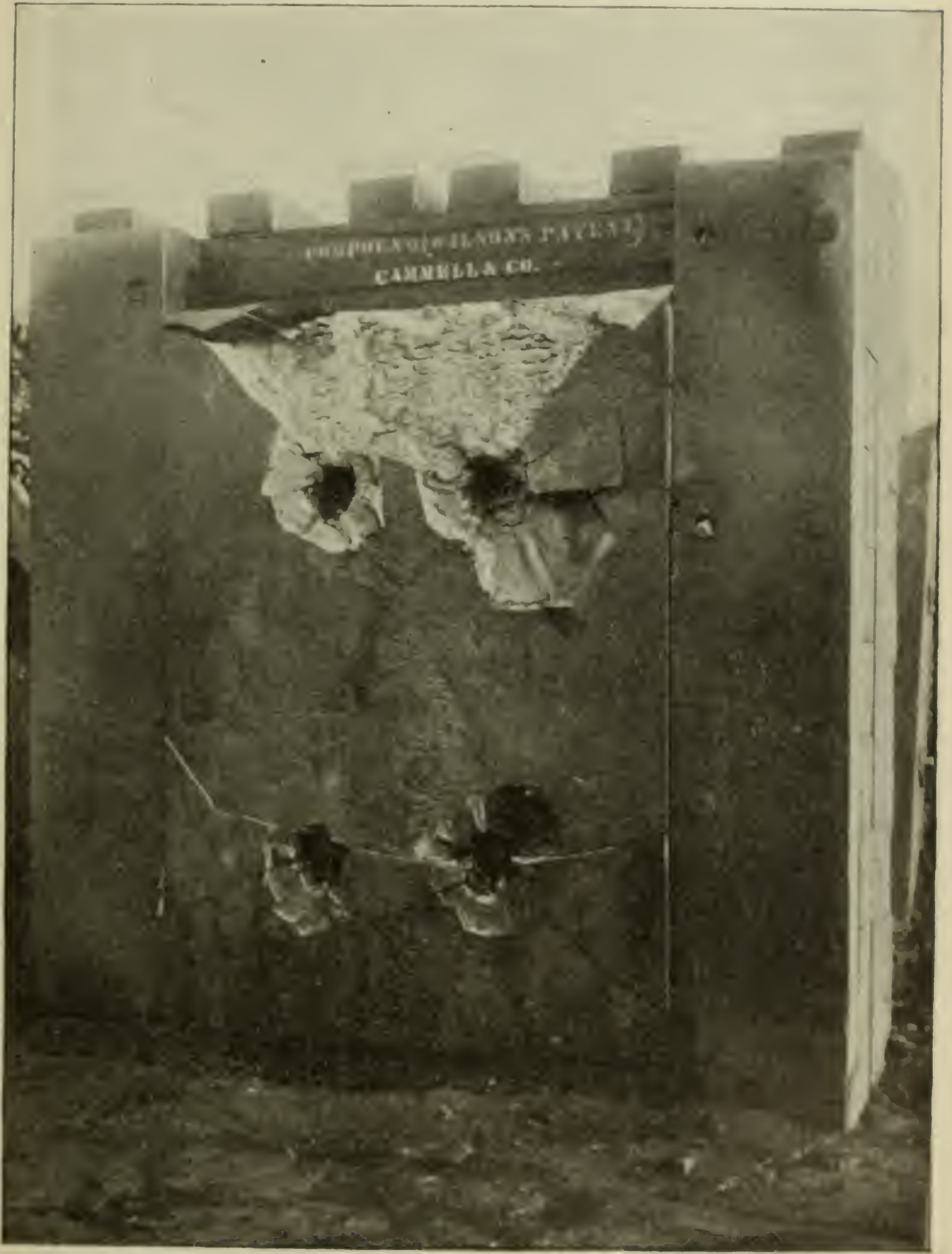

FIG. 5.—Cammell compound plate at Annapolis trials, 1890.

trials of 1890, after the firing of the fourth six-inch Holtzer projectile.

The process of making compound armor by the Ellis patent, as carried out at the Dillingen steel works in Germany, has been described as follows:*

A wrought-iron plate is provided along its longer sides with iron ledges secured to it by steel bolts. These ledges are provided with dovetailed grooves which receive a two-inch covering plate of ·45 per cent. carbon open-hearth steel. This soft steel cover, when rolled down to 0·8 inch in the finished plate, facilitates the subsequent bendings. By this means a five-inch space or mould is provided between the two plates into which the high carbon steel is cast, the two plates or mould being at a bright red heat at the time of the casting. When cool the ledges are removed, the whole reheated and rolled or forged to size.

The margin allowed for carbon in the inner steel stratum is one per cent. above or below standard; for phosphorus, ·025 per cent. provided the carbon is not above the standard, in which case no excess of phosphorus is allowed. Silicon in no case should exceed 0·4 per cent. When tested, a Cammell compound plate of 0·39 per cent. carbon in the steel face, did not prove superior to wrought iron of the same thickness; two others of ·45 and ·48 per cent. carbon were twelve and fifteen per cent. stronger; and a fourth one, with ·56 per cent. carbon gave excellent results. An analysis of one of the best compound English plates was as follows:†

	C.	*Si.*	*Mn.*	*P.*	*S.*	*Cu.*
Layer of steel, ...	·573	·173	·617	·054	·046	·026
Layer of iron, ...	·040	·117	·090	·165	·010	·016

The analyses given by Russian authorities of two similar plates are as follows:‡

							TENSILE STRENGTH.		ELONGATION.	
	C.	*Si.*	*Mn.*	*P.*	*S.*	*Cu.*	*In direction of fibre.*	*Across the fibre.*	*In direction of fibre.*	*Across the fibre.*
Layer of steel, .	0·66	0·10	0·93	0·03	0·05	0·02	93·650 lbs.	88·490 lbs.	1·17%	0·39%
Layer of steel, .	0·62	0·12	0·90	0·20	0·30	0·02	96·200 "	136·500 "	1·9%	1·8 %

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* *Glaser's Annalen*, vol. x, p. 16. *Jour. of the Iron and Steel Inst.*, No. 1, 1882, p. 365.

† *Ibid.*, p. 367.

‡ *Stahl und Eisen*, vol. v, p. 133.

At Spezzia, in 1882, the steel faces of Brown's and Cammell's plates contained, respectively, 0·65 and 0·7 per cent., and Creusot steel plate about 0·45 per cent. carbon.[*]

It seems to the author useless to give any further particulars of the methods of making compound armor, as they are now practically obsolete, and in a few years will be undoubtedly replaced by better methods. In almost every case which has come to his notice within the last two years, compound armor has shown itself inferior to solid steel and alloyed steel plates.

As early as the Spezzia trials of November, 1882, compound plates showed themselves inferior to Schneider's (Creusot) steel plates in certain particulars.

"From an accurate examination of the cracks and the fractured sections, it was observed that in the compound plates the steel, and also the iron, showed rather a coarse grain; distinct strata of the metal imperfectly welded were noticed as well as cavities and traces of scoria. It was also noticed that the thickness of the steel stratum was not uniform, varying from six and one-fourth to four and three-fourths inches. It was noticed that in the weld of the two metals the iron presented a spongy appearance as if of inferior quality.

"In the Schneider plate a very fine grain was observed, uniform and compact, and showing a much greater molecular tenacity."[†]

It should be noted in this connection that the advantages of compound armor or, in fact, any face-hardened armor are, of course, more prominently demonstrated against oblique than against direct firing.

In most cases of armor-plate trials the gun has every advantage, the plate being subject to conditions which would seldom occur in actual warfare. It is rigidly fixed to a backing, the force of the impact of the projectiles must be absorbed by a very small mass of material as compared with a ship's side, besides there is the absence of a structural flexibility or give, existing in the ship, which is no small factor in absorbing the force of the blow. Under the more recent trial conditions the point of impact is normal to the face of the plate, and the gun so close, that the projectile strikes with practically a muzzle energy.

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[*] Capt. Orde Browne, *Journal of the Iron and Steel Inst.*, No. 1, 1884, p. 117.

[†] Report of the Italian Commission. See Very, *Development of Armor for Naval Use. Proceedings of the U. S. Naval Institute*, vol. ix, No 3. 1883, p. 502.

Steel Armor.—The use of iron armor may be said to have ceased and the advent of steel armor to have taken place with the introduction of the 100-ton gun in 1876. At the celebrated Spezzia trials of that year the solid steel plates made by Schneider & Co., of Creusot, showed themselves superior in many particulars to the wrought-iron and sandwich plates subjected to the same tests. Such steel plates as the author has already mentioned, were subsequently adopted by the Italian Government. From this period up to within the last year or so the contest has been between compound and steel armor, the former being developed to its greatest extent in England and the latter in France.

It was not until about the time of the *Nettle* trials of May 19, 1888, that the English made any serious effort to catch up with the French in the manufacture of steel plates; these trials may therefore be considered as marking the beginning of the steel armor making era in England.

One of the plates then tried was made by Cammell and the other by Vickers. They were 8 x 6 feet x 10½ inches, and weighed 9·4 tons. Three a. p. 100-pound Holtzer and two Palliser chilled iron projectiles were fired at each plate —the range thirty feet and the striking energy 2,723 feet.

Cammell Plate.—Round 1 (Holtzer) penetrated 23·3 inches and broke in two, the head remaining in backing and base in plate.

Round 2 (Holtzer) penetrated 13·1 inches and lodged unbroken. Rounds 3 and 4 (Palliser), projectiles broken up, heads remaining in plate. Penetrations not given. Round 5, centre (Holtzer), penetrated 16 inches, lodged unbroken.

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* *The Year's Naval Progress*, p. 289. Office of *Naval Intelligence* Washington, D. C., July, 1891.

No through cracks at all developed. The plate showed, by the difference in the penetrations of the Holtzer projectiles, a decided lack of uniformity in the metal of which it was composed. The bulging on the back was very pronounced, and on the whole the plate cannot be considered equal to an average Creusot steel plate of the same or even an earlier date.

Vicker's Plate.—Round 1 (Holtzer), penetrated thirteen and one-half inches, and rebounded entire. Round 2 (Holtzer) penetrated thirteen inches and rebounded somewhat distorted. One radial through crack developed. Rounds 3 and 4 (Palliser), penetrations slight and projectiles broken up —no through cracks. Round 5, centre (Holtzer), penetrated thirteen inches and rebounded slightly distorted. One short through crack developed,

The penetrations give an evidence of great homogeneity of the metal. The elasticity of the plate was marked by the rebounding of the projectiles.

The general results were such as to lead to the belief that it was very similar in composition to the Creusot steel plates tried at Spezzia in 1876.

Since 1888 the Schneider (Creusot) steel plates have increased in efficiency, their maximum having probably been reached at the Annapolis and Ochta trials in 1890.* Some little progress seems also to have been made in England in the production of steel plates, Messrs. Vickers having received as a result of the *Nettle* trials, a large order from the Admiralty. The day of the steel plate, however, is past, as it will undoubtedly be superseded by the alloyed steel plate.

Lieut. Southerland, U.S.N., in his able review of "The Armor Question in 1891,"† very sensibly says: "The value of steel for armor protection can best be demonstrated by comparing it with the compound metal. With steel plates the face is hardened, but not to the same degree as the face of the compound. This disadvantage, however, even in plates of medium thickness, is more than compensated for by the relatively greater hardness of the back, which tells more and more in favor of the steel as the plates increase in thickness.

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* *The Year's Naval Progress*, 1891, pp. 300 to 328.

† *Ibid.*, p. 332.

"As a result of the softer face, projectiles of medium quality, although broken up by both metals, obtain a greater penetration in steel than in compound, as is evidenced by the French trials, but with a. p. (armor-piercing) projectiles, the resistance of the steel depending on its mass, penetration is less than in compound, where the hard face once overcome, the resistance of the soft back to penetration is but slight."

To the unprejudiced mind the advantages of steel over compound armor are manifest. It is not only more homogeneous than compound, but has the great advantage of being able to be cast into shapes which compound cannot.

As a result of the experiments of the Gavre Commission steel armor was found to possess a superior degree of toughness and elasticity. This property tends to distribute the projectile energy imparted to the plate more uniformly throughout its mass, thus decreasing its tendency to crack and break up, even though the projectile may attain a greater penetration than in the case of a compound plate.

The great inherent defect of solid steel armor-plate is the liability to through cracking. "If this through cracking causes the falling off of the fractured parts, either from succeeding shots or from the motion of the vessel in a seaway, steel would be useless for armor protection; but a careful study of armor trials is conclusive in showing that the system of bolting employed will hold fractured parts in place, unless the plate is excessively fractured by a greater number of blows than one can conceive of its receiving."*

A noticeable feature in steel plates is their tendency to form serrated cracks, as compared with the straight or curved lines of cracks in the compound. This enables fractured parts to dovetail into each other so as to cause them to remain in place, even when unsupported by surrounding plates. It is evident that when badly cracked, the separated parts of steel plates will still offer considerable resistance to penetration. In the recent Annapolis trials, at the end of the fifth round of shots, each of the four separate parts of the cracked steel plate would still have resisted another projectile, while the compound plate, which presented a thickness of less than seven inches of wrought iron, would have been open to perforation by projectiles from as small a rapid-fire gun as the Hotchkiss fourteen pounder.

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* *The Year's Naval Progress.* Office of *Naval Intelligence,* Washington, D.C., July, 1891, p. 332.

About the year 1887, one of the best British authorities, in speaking of steel armor, states that "Creusot steel is not usually as hard as the steel used in the face plates of compound armor, and is as a mass more rigid."[†]

"As compared with compound, steel armor admits the point of the shot at first with less resistance, but it does not yield at the point of impact even where badly backed, and is therefore less dependent on backing than compound armor. As the shot enters, it wedges and heaps up the metal around it, the plate coming forward and swelling at the point of impact and yielding by radiating cracks. It may be questioned if a case could be found of a concentric crack being made in steel armor. Nearly all cracks made extend through the metal, but by the employment of a large number of bolts the fragments may be held up, and considerable resisting power maintained after fracture. On the other hand very soft steel plates admit of perforation, and in their character resemble wrought iron more or less."[‡]

The action of the shot in wedging and heaping up the metal is much the same with nickel-steel plates—which in fact can only be regarded as steel plates strengthened and toughened by the addition of nickel.

Browne states[§] that "steel plates are uncertain in their behavior and are liable to spontaneous fracture after tem-

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[*] *The Year's Naval Progress*, 1891, p. 333.

[†] C. Orde Browne, *Armor and its Attack by Artillery*, part II, p. 85, London, 1887.

[‡] *Ibid.*, part II, p. 85.

[§] *Ibid.*, part II, p. 99.

pering or after annealing." If such was the case eight or ten years ago, it was doubtless due to a want of knowledge and experience in the manufacture of such large. masses of steel. This difficulty has probably been overcome, as we seldom hear of plates cracking spontaneously unless they have been unduly strained.

[*To be continued.*]

THE WORLD'S FAIR.

The World's Columbian exposition, at Chicago, will open on May 1, 1893. The following data give the reader an idea of its scope and magnitude and of its present status and prospects.

The Exposition is under the auspices of the United States Government. Its participants include not only the United States Government and the forty-four States and five Territories of the American Union, but also nearly every foreign government. Its international character is assured.

The foreign nations and colonies which thus far have determined to participate in the exposition, and the amounts of their appropriations, made or officially proposed, as far as information concerning them has been received at headquarters, are the following:

Argentine Republic,	$100,000
Austria,	149,100
Belgium,	
Bolivia,	100,000
Brazil,	600,000
China,	
Chile,	100,000
Colombia,	100,000
Costa Rica,	100,000
Denmark,	
Danish West Indies,	
Ecuador,	125,000
Egypt (informal),	
France,	400,000
Algeria,	
Germany,	214,200
Great Britain,	125,000
Barbadoes,	6,000
British Columbia,	
British Guiana,	25,000
British Honduras,	$7,500
Cape Colony,	25,000
Ceylon,	40,000
India,	
Jamaica,	20,000
Malta,	
Mashonaland,	
New South Wales,	
New Zealand,	
Queensland,	
South Australia,	
Tasmania,	
Trinidad,	15,000
Victoria,	
West Australia,	
Guatemala,	120,000
Hawaii,	
Hayti,	
Honduras,	20,000
Italy (informal),	

Erythria,	
Japan,	$630,675
Korea,	
Madagascar,	
Mexico,	750,000
Netherlands (informal),	
Dutch Guiana,	10,000
Dutch West Indies,	5,000
Nicaragua,	30,000
Orange Free State,	
Paraguay,	25,000
Persia,	
Peru,	125,000
Russia,	
Salvador,	$12,000
San Domingo,	
Siam,	
Spain,	
Cuba,	25,000
Transvaal,	
Turkey,	
Uruguay,	
Venezuela,	
Total,	$4,004,565

Thirty-nine nations.

Twenty-four colonies.

Bolivia appropriated $10,000 for preliminary expenses, and authorized its President to draw on the regular diplomatic appropriation for any further sum needed, the whole amount estimated to be necessary being $100,000. Of Ecuador's $115,000, the city of Guayaquil furnishes $25,000. Paraguay has authorized its President to spend whatever sum may be necessary to have the country creditably represented. It is reported that $25,000 of expenditure is contemplated. Mexico has voted $50,000 for preliminary expenses. No doubt is felt that the balance of the $750,000 proposed will be forthcoming. It is assured that quite a number of the appropriations named above will be increased.

From information received at Exposition headquarters, it can be said to be almost assured that there will soon be added to the above list Norway and Sweden, Hungary, Switzerland, Canada and several others. At a low estimate the total of the appropriations of foreign nations will reach $5,000,000. Nearly all of the participating nations will erect buildings in the exposition grounds. Building sites have already been selected for Great Britain, Germany, Japan, Turkey, Mexico, Peru, Brazil, Ecuador, Colombia, Costa Rica, Guatemala and Chile. The buildings of foreign nations will present most varied contrasts in respect to size, architecture and adornment.

The United States Government has appropriated thus far $1,500,000, of which $400,000 was set apart for its building and $250,000, approximately, has been drawn for the cost of five sessions of the National Commission, two sessions of the Board of Lady Managers, the salaries of the officers and employés of these two bodies, and the expenses of three special agents of the Treasury Department who were sent to Europe to explain to foreign commissions and governments the regulations of the department governing the importation of exhibits. A considerable portion of the remainder has been spent in preparation of the Government exhibit by the Board having the matter in charge. The Congress now in session is expected to appropriate a sum sufficient for the future expenses of the National Commission and Lady Managers, and the continued preparation of the Government exhibit, and also about $700,000 for the exposition awards and the payment of the awarding juries, as obligated by the Act of Congress creating the National Commission. The Government, as elsewhere stated, has been asked, also, to appropriate something for a District of Columbia exhibit, and $5,000,000 in general aid of the exposition.

Twenty-six States and two Territories, thus far, have made appropriations for their representation at the exposition, as follows:

Arizona,	$30,000	New Hampshire,	$25,000
California,	300,000	New Jersey,	20,000
Colorado,	100,000	New Mexico,	25,000
Delaware,	10,000	North Carolina,	25,000
Idaho,	20,000	North Dakota,	25,000
Illinois,	800,000	Ohio,	100,000
Indiana,	75,000	Pennsylvania,	300,000
Iowa,	50,000	Rhode Island,	25,000
Maine,	40,000	Vermont,	15,000
Massachusetts,	75,000	Washington,	100,000
Michigan,	100,000	West Virginia,	40,000
Minnesota,	50,000	Wisconsin,	65,000
Missouri,	150,000	Wyoming,	30,000
Montana,	50,000		
Nebraska,	50,000	Total,	$2,695,000

In several of these States the appropriations made are only preliminary, and will be largely increased. In Iowa, for example, the Executive Committee of the State Commission has prepared estimates aggregating $339,000, and will ask the Legislature to appropriate accordingly. Colorado, Maine, Massachusetts, Minnesota, New Jersey and West Virginia promise increased appropriations. In Colorado, an additional $50,000, approximately, has been voted by the counties, and in Indiana about $10,000 has been raised by school pupils and teachers. In California, too, some of the counties are supplementing the State appropriation.

Nine States which, owing to constitutional restriction, or other prohibitive reason, made no World's Fair appropriation, have held State conventions and formed organizations of the stock-subscription sort for raising the amounts deemed necessary for creditable representation. These States, and the sums they are thus raising, are:

Alabama,	$50,000	Oregon,	$100,000
Arkansas,	100,000	South Dakota,	80,000
Florida,	100,000	Tennessee,	100,000
Georgia,	100,000	Texas,	300,000
Kansas,	100,000	Total,	$1,030,000

The legislatures of several States which have made no provision for representation are now in session, or soon will be. In Maryland, a bill for $100,000 is pending. In New York, a bill for $250,000 has been introduced, and a second bill for $500,000 is advocated by several influential organizations, which believe that sum necessary for creditable representation. Nearly all of the States and Territories that have not already made liberal appropriations, are expected to do so in time. It is reported that the Government will be asked to appropriate $50,000 for the representation of the District of Columbia, and perhaps something for an Alaska exhibit. The aggregate expenditure by the States and Territories is expected to reach $5,000,000.

Information concerning the State Buildings is yet quite incomplete, as but few of the plans have been approved. It is expected that nearly all will erect buildings as State headquarters and receptacles for collective exhibits illustrating their resources. Thus far, data for the buildings of twenty-two States, as projected, have been received at headquarters. These structures, for the most part, will be two stories in height; will average about 50 x 75 feet in dimensions, and will cost from $10,000 to $100,000 each.

The size and cost of the great exposition buildings are indicated in the following table:

BUILDINGS.	Dimensions in Feet.	Area in Acres.	Cost.
Manufactures and Liberal Arts,	787 × 1687	30·5	$1,500,000
Administration,	262 × 262	1·6	435,000
Mines,	350 × 700	5·6	265,000
Electricity,	345 × 690	5·5	401,000
Transportation,	256 × 960	5·6	370,000
Transportation, Annex,	425 × 900	8·8	
Woman's,	199 × 388	1·8	138,000
Art Galleries,	320 × 500	3·7	670,000
Art Galleries, Annexes (2),	120 × 200	1·1	
Fisheries,	165 × 365	1·4	224,000
Fisheries, Annexes (2),	135 diameter.	·8	
Horticulture,	250 × 998	5·7	300,000
Horticulture, Green-houses (8),	24 × 100	·5	25,000
Machinery,	492 × 846	9·6	1,200,000
Machinery, Annex,	490 × 550	6·2	
Machinery, Power-house,	100 × 461	2·1	85,000
Machinery, Pumping Works,	77 × 84		
Machinery, Machine Shop,	146 × 250		
Agriculture,	500 × 800	9·2	618,000
Agriculture, Annex,	300 × 550	3·8	
Agriculture, Assembly Hall, etc.,	125 × 450	1·3	100,000
Forestry,	208 × 528	2·5	100,000
Saw Mill,	125 × 300	·9	35,000
Dairy,	100 × 200	·5	30,000
Live Stock (3),	65 × 200	·9	335,000
Live Stock, Pavilion,	280 × 440	2·8	
Live Stock, Sheds,	—	40·7	
Casino,	120 × 250	·7	210,000*
Music Hall,	120 × 250	·7	
		153·8	$7,041,000
U. S. Government,	345 × 415	3·3	400,000
U. S. Government, Imitation Battle-ship,	69·25 × 348	·3	100,000
Illinois State,	160 × 450	1·7	250,000
Illinois State, Wings (2),	—	·3	
		159·4	$7,791,000

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* Including connecting peristyle.

The last three are being erected, the first two by the United States Government, and the third by the State of Illinois. The visitor, however, will naturally class them among the great exposition structures.

The exposition buildings, not including those of the Government and Illinois, have also a total gallery area of 45·9 acres, thus making their total floor space 199·7 acres. The Fine Arts building has 7,885 lineal feet, or 145,852 square feet of wall space.

All of the annexes will be scarcely less imposing and architecturally beautiful than the main buildings themselves. The live-stock sheds, which will cover an immense area as indicated, are to be constructed as inexpensively as possible without marring the general architectural effect. The power-houses, pumping works, etc., are to be exhibits in themselves, and so constructed as to be readily inspected by visitors. There will be several exposition buildings in addition to those named, but data concerning them are not yet fully determined. Among them will be a Press building, in which every possible convenience and accommodation for the press representatives of the world will be provided; and a reproduction of the Spanish convent, "La Rabida," in which a wonderfully complete collection of Columbus relics and allied exhibits will be gathered. The total cost of the exposition structures alone is estimated at $8,000,000.

The amount ($8,000,000) which the Exposition Company expects to expend upon buildings represents less than one-half of its total estimated expenditure for the great enterprise. Following are estimates of various other expenses prepared by the Ground and Buildings Committee:

Grading and filling, etc.,	$450,400
Landscape and gardening,	323,490
Viaducts and bridges,	125,000
Piers,	70,000
Waterway improvements,	225,000
Railways,	500,000
Steam plant,	800,000
Electricity,	1,500,000
Statuary on buildings,	100,000
Vases, lamps and posts,	50,000
Seating,	8,000
Water supply, sewerage, etc.,	600,000
Improvements of lake front,	200,000

World's Congress Auxiliary,	$200,000
Construction department expenses, fuel, etc.,	520,000
Organization and administration,	3,308,563
Operating expenses during Exposition,	1,550,000
	$10,530,453

Add to this the amount estimated to be necessary for buildings ($8,000,000), and the grand total sum to be expended by the Exposition Company stands at $18,530,453. This does not include, of course, the expenditure by the United States Government, the States of the Union, or foreign countries. Of this $18,530,453, about $17,000,000 must be paid out before the gates of the Exposition are thrown open to the public, on May 1, 1893. The total amount which the Exposition Company has paid out up to date, for all purposes, is $2,779,707. Owing to the present enormous demands of construction, the expenditure is now running at nearly $1,000,000 a month.

In view of the showing given above, a statement of the Exposition's resources will be found interesting in this connection.

RESOURCES.

Stock subscriptions,	$5,721,230
City of Chicago bonds,	5,000,000
Prospective gate receipts,	10,000,000
Concessions and privileges,	1,500,000
Salvage,	1,500,000
Interest on deposits,	33,452
Total,	$23,754,682

To the resources will be added future interest on bank deposits and future subscriptions to stock. New subscriptions are coming in daily, and the amount which will thus be realized is certain to be large, though how much it will be can now only be surmised. An increase of $200,000 from these sources is a safe estimate. On the other hand, some deduction must be made for delinquency in the payment of subscriptions to stock. Thus far, sixty per cent. of the subscribed amounts has been called for, and $3,433,800, or more than sixty per cent. has been actually paid in, quite a number of subscribers having voluntarily paid up in full without waiting for the successive calls. The subscribers number about 30,000. Among subscribers there have been nearly 500 deaths, and this, together with impoverishment, etc., has caused thus far a delinquency in collections of between seven and eight per cent. of the amount due. This is less than was anticipated. Making a very liberal allowance for delinquencies, the net resources, as estimated, stand in round numbers at $23,350,000, or about $4,825,000 in excess of the total estimated necessary expenditure.

But of the resources the gate receipts, concessions and privileges, and salvage, representing a total of $13,000,000, are not only estimates but are necessarily prospective. They cannot be realized even in part until the exposition opens and is in progress. The salvage from the disposal of the buildings cannot, of course, be realized until after the fair closes. It follows that the resources available previous to the opening of the exposition, by which time, as explained above, $17,000,000, approximately, must be expended, are cut down to about $10,750,000. It will be seen that about $6,250,000 must be provided for in some manner. Accordingly, the United States Government may be asked to aid the exposition by taking a financial interest in it to the extent of $5,000,000. In view of the fact that the National Commission, representing the Government, in adopting the classification of exhibits, made the scope of the exposition so extensive that, as the Exposition Directory has found, it could not possibly be creditably fulfilled within the expenditure of the $10,000,000 which was at first deemed sufficient—and which Chicago has provided, according to promise—it is believed that Congress will consider it incumbent upon the Government, both in point of actual obligation and that the national honor may be maintained before the world, to provide the means for meeting the excess of expenditure which the action of its representative rendered necessary. With such assistance, to the extent of $5,000,000, the Exposition Company believes it will be able to meet all demands.

The actual erection of the exposition buildings began in June, 1891. Now all of them are being pushed rapidly towards completion. Already several are under roof. About 4,000 workmen are employed. Work proceeds day and night.

Woman's Building.—This is farthest advanced of all. It is roofed and almost completed exteriorly. Covered and adorned with "staff," it appears like a marble palace. The furnishing of the interior is proceeding.

Mines Building.—The framework is up, and finishing touches are being put on the iron and glass roof. The "staff" is being applied.

Electricity.—Framework completed up to gallery floor, and nearly all of the great steel trusses for the roof in place.

Horticulture.—The pavilions are up to the roof line. The west portion is roofed and windows are being placed. The iron work of the dome is being put in position.

Transportation.— Framework practically completed, as also roof sheathing over galleries. Clere-story trusses are being raised.

Administration.—Structural work of the four pavilions completed and exterior covering being applied. Iron work in place up to base of dome, 170 feet from ground.

Machinery Hall.—Floor and 6,000 supporting piers completed; superstructure going up, and foundation for annex being laid.

Agriculture.—Interior columns and gallery girders and joists in position, and the great iron columns supporting the roof being placed. Of the 7,000,000 feet of lumber which the building will contain, more than half is already utilized.

Manufactures and Liberal Arts.—The thirty and one-half acres of flooring are laid, and the superstructure is begun. The huge steel trusses for the roof, which together will contain more metal, by fifty per cent., than the Brooklyn bridge, will soon be raised.

Art Galleries.—Basement and floor are completed, and the brick walls have reached an average height of ten feet above the second floor. More than 5,000,000 brick are already laid.

Fisheries.—The gallery trusses of the main building are placed, and the iron framework of both pavilions is completed.

Forestry.—This is about three-fourths finished, and will be occupied by the model makers until spring, when the outside rustic work will be put on, and the temporary roof will be replaced by a thatched one.

Dairy.—All the columns are up to the roof line, and the gallery floor is being laid.

Work on the Illinois State building and on the United States Government building is being pushed rapidly. The imitation battle-ship is completed to the deck level.

Insurance is placed and increased on the buildings as their construction proceeds. The amount now carried is above $1,000,000. During the exposition, it is estimated not less than $150,000,000 or $200,000,000 of insurance will be carried on the buildings and exhibits.

All possible precautions are taken against fire. The exposition grounds are already provided with a full equipment of fire engines and apparatus.

In the construction of the buildings about 60,000,000 feet of lumber and 18,000 tons of steel and iron will be used. In their adornment will be utilized nearly 84,000 pieces of ornamental "staff" work, of which about one-third are already completed.

To supply the exposition buildings and grounds with water two plants are being put in, one with capacity of 24,000,000 gallons a day, and the other of 40,000,000 gallons. Thus 64,000,000 gallons a day will be available. The pumping works and all of the great machinery furnishing power to the exposition will be open to the inspection of visitors.

A system for drainage, believed to be adequate and perfect, has been adopted. Perfect sewerage, too, is planned. All refuse from the *cafés* and kitchens, and from the lavatories and closets, of which 6,500 will be constructed at an expense of some $450,000, will be received by injectors, and forced by compressed air through underground pipes into four huge tanks, where it will be treated chemically and rendered entirely inoffensive. Work upon these systems is progressing.

Plans adopted for lighting the buildings and grounds provide for 138,218 electric lamps, of which 6,766 are to be arc lamps of 2,000 candle-power each, and 131,452 incandescent, sixteen candle-power each. The electric lighting will cost something like $1,500,000 and will be ten times as extensive as was employed at the Paris exposition. The light and motive plant at the exposition, it is estimated, will require 26,000 horse-power, of which 22,000 will be required for the electric plant.

Transportation to and from the exposition, both for visitors and exhibits, will be as perfect as it is possible to make it, both in the matter of facilities and rates. Greatly reduced rates on all railroads and some of the steamship lines will prevail. Definite arrangements are yet to be perfected. Much attention is being given to the question of furnishing abundant facilities for reaching the grounds from all parts of Chicago, and it can be asserted that existing means, already extensive, will be increased so that a maximum of 400,000 a day can be carried to and from the grounds. For the transportation of exhibits, arrangements have already been made with nearly 500 railway and steamship lines, including all of the trunk railroads and more important lines in the United States. Of these transportation lines, 417 have agreed to charge regular tariff rates on exhibits to the exposition, and to return them to starting points free of charge, provided their ownership remains unchanged. Thirty-seven have agreed to charge half regular rates both ways, and thirty-three have promised to transport them free both to and from the exposition. The Atlantic Transport Line of Steamers, which runs freight steamships between London and New York, Philadelphia and Baltimore, will make no charge on exhibits in either direction, except on such as, owing to their excessive size or weight, require extra help in their handling. In such cases only the expense of the extra help will be charged. Foreign exhibits will be admitted free of all duty. Such exhibits, however, if sold in this country, will be subject to payment of regular customs duties.

The World's Congress Auxiliary.—This is organized to provide for the presentation, by papers, addresses and discussion, of the mental and moral status and achievements of the human race. Under its auspices, a series of congresses will be held in Chicago during the progress of the exposition, in which, it is already assured, will participate a great many of the ablest living representatives in the various fields of intellectual effort and moral endeavor. The Auxiliary embraces between fifteen and twenty main departments, such as Literature, Government, Education, Music, Science, Art, Engineering, etc., in each of which are subdivisions. A programme is being arranged for congresses in each of these departments and divisions, in which specialists and advanced thinkers may participate in discussing the vital and important questions, and presenting the best and latest achievements of the human mind in each. During the exposition the Auxiliary will have the use of a magnificent permanent Art Palace, which the Chicago Art Institute, aided by the Exposition Directory, is about erecting on the lake front. This will have two large audience rooms, each of 3,500 capacity, and from twenty to thirty smaller rooms, of capacity ranging from 300 to 750. The great auditorium will also be utilized for the larger congresses, and numerous other halls are available when required. Each congress will be supervised by a committee of persons actively interested in its particular field, acceptance of such responsibility having already been given. The prospects are that fully 100 congresses altogether will be held. It is the intention to publish their proceedings in enduring form. Detailed information concerning the Auxiliary, or any of its departments or divisions, can be obtained of its President, Charles C. Bonney.

The participation of women in the exposition promises to be one of its most interesting as well as novel features. With a commodious and imposing building, designed by a young lady architect, and with an abundance of money, and with full recognition, indorsement, and aid by the United States Government and the Exposition Directory, the women have an opportunity of showing, in most signal manner, the condition of their sex throughout the world; what are the achievements of woman in the various branches of human endeavor, and what is her adaptability to different occupations and lines of industrial and charitable work. Under the direction of the Board's President—Mrs. Potter Palmer—the work of organization, and of enlisting the interest of women throughout the United States and in foreign countries, has progressed to a most satisfactory stage.

Jackson Park and Midway Plaisance—the Exposition site—are in the southeastern part of Chicago, and embrace 664 acres, with a frontage of about a mile and a half on Lake Michigan. Forty-five miles of boulevard connect the site with the general park system of Chicago, which embraces fifteen or more parks, aggregating 2,000 acres.

Half a million dollars has already been expended in grading Jackson Park and dredging extensive waterways throughout it. Hundreds of thousands are yet to be spent for landscape gardening, fountains, statuary, pleasure boats, etc. A number of observation towers, from which excellent views of the buildings and grounds can be obtained, will be erected in different parts of the Park.

According to present plans fully 150 restaurants and *cafés* will be in operation in the various buildings and about the grounds. These will be conveniently distributed, and will have an estimated aggregate seating capacity of 6,000 or 8,000.

Midway Plaisance, connecting Jackson Park with Washington Park, will be occupied throughout its entire length by special Exposition features largely of a foreign character, such as the "Bazaar of All Nations," "Street in Cairo," "Street in Constantinople," "Moorish Palace," "Maori Village," etc., to which concessions have been granted, and which, in their production, will represent the expenditure of hundreds of thousands of dollars. Panoramas, cycloramas, the sliding railway, etc., will also be located there.

A single entrance fee, probably fifty cents, will entitle visitors to see the entire exposition proper. The special attractions on Midway Plaisance will make a moderate additional charge.

The hotel accommodations of Chicago, already very extensive, are being augmented by the erection of fully twenty new hotels, some of which are very large. Two million dollars or more are to be spent by the city and the Park Commissioners, in putting the streets, parks, etc., in presentable condition against the influx of visitors.

It may be said to be assured that the exhibits at the exposition will cover a wider range and be far more numerous than were ever before gathered together. They will present a picture of the condition and industrial progress of mankind in every quarter of the world, and of its achievements in every branch of the sciences and arts. The exposition classification embraces twelve departments, 176 groups, and 967 classes. The application for space by intending exhibitors in the United States alone, numbered 2,082 on January 1st. The number at the Philadelphia Centennial on corresponding date was 864. Applications from foreign exhibitors are reported very numerous and rapidly increasing. It seems assured that the exhibitors will outnumber those at any previous world's fair. The allotment of space will be made about June. The reception of exhibits will begin November 1, 1892, and continue until April 10, 1893. No charge will be made for space for exhibits.

The exposition buildings, as required by Act of Congress, will be dedicated "with appropriate ceremonies" on October 12, 1892, the 400th anniversary of the discovery of America by Columbus. The exercises will occupy three days, beginning on the 11th and closing on the 13th with a grand dedication ball. The committee having the matter in charge has planned to make the ceremonies most impressive in character. Something like $300,000 will be spent to secure this end. The President of the United States and his Cabinet, the Senate and House of Representatives, the Governors of the several States with their staffs, and representatives of all foreign nations will be invited to be present. The mobilization of 10,000 militia and several thousand regulars is planned, as is also an imposing civic and industrial display. In the evenings there will be a magnificent display of fireworks, and in the Park waterways a pageant of symbolical floats, representing the "Procession of the Centuries." In the dedicatory exercises on the 12th, the complete buildings will be tendered by the President of the Exposition to the National Commission. President T. W. Palmer will accept them on behalf of that body and will at once present them to the President of the United States, who will fittingly respond. The dedicatory oration will follow. Much attention is being given to the musical portion of the programme. This will include a dedicatory ode and orchestra marches written for the occasion. These and other numbers, including "America" and "Star Spangled Banner," will be rendered with full choral and orchestral accompaniment.

In April, 1893, a grand international naval review, preliminary to the opening of the exposition, as provided for by Act of Congress, will be held in New York harbor. Arrangements for this are now being made.

The exposition will open its doors to the public on May 1, 1893, and close them on October 30th, of the same year.

A PRACTICAL CONSIDERATION OF COMPRESSED AIR.

By Wm. L. Saunders, C.E.

[*A lecture delivered before the Franklin Institute, December 11, 1891.*]

In an address recently delivered before this Institute and published in the *Journal* for July, 1891, Dr. Coleman Sellers, in referring to the utilization of the power at Niagara Falls, used the following words:

"You may wonder why compressed air is thought of at all for transmission, as you have known in America that it has been thought to be a very wasteful manner of transmitting power, but the recent improvements that have been made in compressors have very much changed the condition of that mode of transmission, and the fact that so much gain is possible by reheating the air indicates a cheap power which can be transmitted long distances with economy."

This concise and truthful statement has been selected as a text for what I have to say on the subject of compressed air, because, in the first place, it calls attention to the very general impression which exists in America as to the "very wasteful manner," by which power is transmitted by compressed air, and it suggests the true solution of the problem, which is in the direction of improvements in air compressors and reheating the air.

Compressed air, though one of the oldest of the sciences, is in its development and use one of the youngest. Hero of Alexandria, a century before Christ, experimented and wrote upon "Pneumatics," calling special attention to the influence of heat in expanding and contracting air, and Prof. Thurston has given us an account of an invention which was put into practical use by Hero, by which the opening and closing of temple doors was effected by the alternate rarefaction and condensation of air which was brought in contact with heated and cooled surfaces of altar tops. Yet the science of pneumatics played no important part in industrial progress until scarcely more than a century ago it came into general use for diving-bells, and later on it was applied by Brunel to caisson work.

The use of compressed air in America has been confined almost exclusively to mining, tunnelling, bridge building and work in a confined space for which no other power was available. The question has not been one of economy of power, but of durability of apparatus, low first cost, light weight, economy of space and general availability for the purpose. Dry, pure air delivered at a sufficient pressure by a machine which could be depended upon, has been the controlling consideration. Such a condition of things offers no stimulus in the line of fuel economy, and it is only during recent years and since the use of compressed air has been extended to work above ground, that the percentage of power delivered in proportion to that consumed has been recognized as a thing of great importance in the science.

Since the necessity of economy in the production and use of compressed air power became recognized, the question has been considered and the science developed by two distinct classes of men, the theorists and the practical men. The theorists are the professors and engineers whose skill as mathematicians has enabled them to indulge in such an array of figures, and to produce so many cobwebs in diagrams relating to the expansion and contraction of gases, and bearing upon the intricate laws of thermodynamics, that the more practical engineers have avoided the subject as one which belonged only to specialists. The practical men have been left to themselves to make improvements, and have made slow progress because they did not possess the proper theoretical knowledge. In other words, that true combination of theory and practice which leads to the best results has been wanting among pneumatic engineers.

The whole question of compressed air economy is based upon

(1) Economy of production;

(2) Economy of use.

Transmission calls for but little consideration. This statement will doubtless surprise many who look upon the losses suffered in the use of compressed air as due largely to transmission, and no better evidence is needed of the obscurity of the science, even among engineers, than this fact. There is not a properly designed compressed air installation in operation to-day that loses over five per cent. by transmission alone. The question is altogether one of the size of pipe, and if the pipe is large enough the friction loss is a small item. It is undoubtedly true that there are places where a conduit has been laid for a certain volume of air, and where the supply has been increased without increasing the size of the conduit, the result of this being that more air is forced through the pipe than its sectional diameter will admit economically; hence the velocity of flow is increased, and as the friction is in direct proportion to the velocity, the loss of power is also increased. The largest compressed air power plant in America is that at the Chapin Mines in Michigan, where the power is generated at Quinnesec Falls, and transmitted three miles. This is not an economical plant, but the loss of pressure as shown by the gauge is only two pounds, and this is the loss which may be laid strictly to transmission. I recently visited the Jeddo Tunnel, near Hazelton, Pa., where compressed air at sixty pounds pressure is conveyed 10,860 feet. They told me that they had tried the gauges on both ends of the line, and had found no difference whatever in pressure, but that the gauges had been sent to the shops for repairs as they were convinced that "something was wrong." The result was not changed when the gauges had been "repaired," and it was evident that this apparently perfect economy of transmission was due to the fact, that a large pipe (five and three-fourths inches in diameter) was used to convey so small a volume of air, that the velocity in the pipes produced so small a friction loss that it could not be recorded on the gauge.

A question commonly asked is, How much power is lost in using compressed air? I usually reply, fifty per cent., because a proper qualification of the question will result in figures in one case below and in the other above fifty per cent. If compressed air is produced by the best modern air compressor, and used by the best modern engine *immediately at the compressor*, the loss is only that which is suffered when using any like engine, and is confined in its greatest extent to the question of engine friction, and is only to a small degree influenced by shrinkage of volume through radiation, clearance loss, leakage, etc. In such cases the loss varies between ten and twenty-five per cent., but such cases are rare, because it would obviously be more economical to use the steam direct.

The usual conditions of compressed air use are those where the air engine is situated from 1,000 feet to several miles from the compressor. In most cases the distance is so great that the compressed air enters the engine at a temperature equal to that at which it entered the compressor. Were it possible to produce compressed air isothermally; that is, without increase of temperature during compression, the service would be economical even at low temperatures, but isothermal compression has never been realized, and the heat produced during compression (which is the exact equivalent of the power applied) is suffered to increase the pressure, and hence to increase the resistance to compression, without a relative increase of volume. Hot air under pressure is discharged into a receiver, and the gauge indicates a pressure of (say) sixty pounds, which is equal to that recorded by the gauge 10,000 feet away, yet it is a false indication as affecting the question of power, because every cubic foot of sixty pounds air at the compressor is less in weight than an equal volume of equal pressure air at the engine, in exact proportion to the difference in temperature. The result of this is that an air engine which uses (say) 100 cubic feet of sixty pounds air per minute at the temperature of the surrounding atmosphere, really uses about 150 cubic feet of sixty pounds air at the receiver temperature. All this is very important in looking for a remedy for compressed air losses, because it points to the influence of heat upon air, and the importance of reheating compressed air.

The loss of power in common practice where compressed air is used to drive machinery in mines and tunnels, is about seventy per cent. I refer to cases where common American air compressors are used, and where the air is transmitted far enough to lose its heat of compression and is exhausted without reheating.

In the best practice, with the best air compressors, and without reheating, the loss is about sixty per cent.

These losses may be reduced to a point as low as twenty per cent. by combining the best systems of reheating with the best air compressors. In France, England and Germany there have been erected during recent years large compressed air installations. In Paris about 25,000 horsepower is transmitted over the city and is used to drive engines and for many other purposes. With a less efficient production than our American system, they have advanced beyond us in the use of compressed air. Reheating has been put into general use, while here in America the improvements have been more conspicuous in the air compressor. Prof. Kennedy, whose elaborate report on the Paris plant is accepted as an authority, uses the following words:

"Summarizing now the whole matter as regards effi ciency, it may be said that the result of my detailed investigations is to show that the compressed air transmission system in Paris is now being carried on, on a large commercial scale, in such a fashion that a small motor four miles away from the central station can indicate in round numbers ten horse-power, for twenty horse-power at the station itself, allowing for the value of the coke used in heating the air."

Prof. Kennedy concludes his report by saying, "Nothing, indeed, can be easier (as was evident on the recent visit of the Institution of Mechanical Engineers to St. Fargeau) than to point out various weak points in the arrangements adopted." We may reasonably expect to add to this fifty per cent. efficiency attained in Paris by an installation which combines the American compound condensing Corliss air compressor with an efficient and economical reheating apparatus and Corliss or other economical engines.

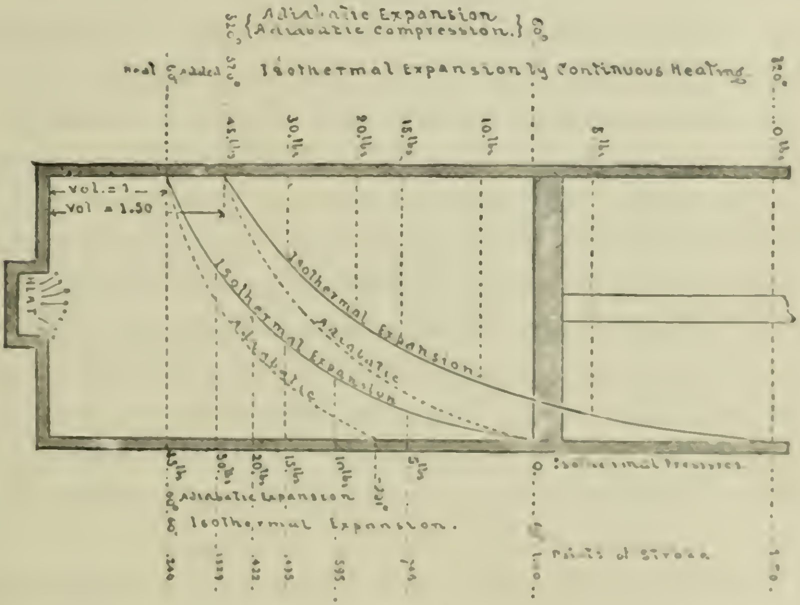


FIG. 1.

The whole science of the production and use of compressed air can be best understood by a simple practical illustration.

Fig. 1 is an open cylinder which may be made to illustrate at the same time the air compressor and the air engine. The piston at the point shown is supposed to confine a volume of free air in the cylinder and at a temperature of 60°. Let it be pressed down until it reaches the point indicated by forty-five pounds at the left, and the pressure will follow the dotted line marked "Adiabatic." This is, of course, assuming that the heat, which is invariably produced by compression, is suffered to remain in the air and to influence the pressure. We here have a confined volume of compressed air at a pressure of forty-five pounds and a temperature of 320°. Let there be no absorption of heat and the piston if released will return to the starting point, the pressure following exactly the line indicated during compression and the temperature returning to 60°. In such a case we assume, of course, that the piston is frictionless. This points to the fact that compressed air is a perfect spring, and that the heat of compression when utilized can be made to return its full value of energy.

An air compressor in spite of its cooling apparatus usually furnishes compressed air at pressures following closely the adiabatic line, so that the illustration applies to a typical case so far as the compression is concerned. This subject of adiabatic compression has been fully referred to, and the difficulties which have stood in the way of isothermal compression have been pointed out in a pamphlet written by me about a year ago, entitled *Compressed Air Production*, published by the *Engineering News* Publishing Company, New York.

We have now seen that the heat of compression is not such a serious thing provided it can be utilized. The hot compressed air confined below the piston at the forty-five pound point, if transferred through pipes or otherwise to an air engine and maintained hot, will do as much work as we have just seen is possible when applied to the air compressor itself in driving the piston back to the starting point. To convey this air some distance hot, is a difficult matter, for compressed air though very slow in taking up heat, has so low a specific heat that it parts with its temperature rapidly. This loss of heat is the only serious obstacle, because, as we have seen, the friction loss in the pipe is not serious, and experiments have conclusively proved that leakage in a good system cuts no figure in the loss of power. I have pointed out in *Compressed Air Production*, the reasons why clearance loss is of little consequence in an American air compressor. This is especially true in adiabatic compression because here what little clearance there is serves only to confine hot compressed air which acts as a spring, and which gives out a full return of power when the stroke is reversed.

As air parts with its heat rapidly, we cannot advise saving the heat during transmission by covering the pipe, so that we now suffer the loss of heat during transmission to go on, depending upon *restoring* the heat immediately at the air engine. Now this reheating is not, as some may suppose, a means by which the gain is only equal to the expenditure. Air is almost a perfect gas, and the application of heat is a direct transfer of energy to a substance which, through its elasticity, is capable of giving a full return. We burn a pound of coal under the boiler, and get only about ten per cent. back in power, because of the large loss in the stack, the loss in the exhaust, the difficulties in the way of utilizing the latent heat, etc., but when we heat compressed air, the thermal energy in the coal is stored in the air, and we are only limited in our efforts to utilize *all* of it by the reduction of pressure which takes place more rapidly than the reduction of temperature, and hence a warm exhaust. Radiation of heat between reheater and engine is also a source of some loss.

Returning to *Fig. 1*, let us imagine that the piston has been stopped at the forty-five pound point, and that this air, which, as we have seen, has a temperature of 320°, is transferred into a receiver and used at a point a mile away. The temperature will now be reduced to 60°, and if the system is well designed, we have nearly forty-five pounds pressure on the other end of the line, so that the volume of air will be reduced in size corresponding with the space underneath the lowest horizontal dotted line in the figure. This is marked "Volume 1." It is now used without reheating, to do work in an engine, and the line of reduction in pressure will now follow the lower dotted line marked "Adiabatic" until it reaches the point marked — 201°, which will represent the temperature of the air when exhausted at atmospheric pressure. We now see that instead of getting back to the starting point the piston has only power enough to return about half-way.

If, on the other hand, heat were applied *during expansion*, the pressure would follow the line marked "Isothermal Expansion" and the piston would return to the starting point.

Another case is shown by the figure in which the air is compressed adiabatically to forty-five pounds, and heat enough is applied during expansion to maintain the temperature at 320°, until the air is exhausted at atmospheric pressure. This case illustrates the possibility of obtaining more power out of a given volume of air after compression than was expended at the compressor.

Reheating compressed air may be divided into two systems:

(1) That in which the reheating takes place in the conduit and before the air passes the valve of the engine.

(2) Reheating in the cylinder of the air engine after admission and cut-off.

The first case is the common practice, and is of value in that it saves *air volume*. It cannot increase the pressure because there is a continuous elastic air connection between the receiver at the compressor and the heater. Compressed air which leaves the receiver at a temperature of 300°, and which passes through a large conduit, losing its temperature, maintains its pressure because of this continuous elastic connection.

The reheater serves to reduce the *velocity* with which the air is drawn through the pipe, because it delivers hot air to the engine at the same pressure as though there were no reheater, and the temperature being higher, the power in each cubic foot of air remains the same though the *volume weight* is less. This valuable service performed by the reheater is limited only by the fact that air engines cannot work to advantage at temperatures over 350°; hence in a system that compresses air adiabatically to about sixty pounds pressure, and delivers it cold at a reheater, it is possible to restore the temperature to the original point, and thus lose in power only through friction of the compressor, consumption of coal in reheater, friction in conduit, leakage, etc.

The second case is a problematical one, as thus far it has not been found practicable to reheat directly *in* the engine. The only device which seems to offer encouragement in this line is the system of internal reheating, which the writer has applied with some success, and which will be described later on. By internal reheating *directly against the piston of the air engine* an enormous advantage can be gained, and, as shown by *Fig. 1*, more power may be derived from a volume of compressed air than was originally expended at the compressor. This aditional power has been derived directly through heat acting upon the intrinsic energy which was stored in the free air before it entered the compressor.

The Paris reheater is simply a coke stove which surrounds the air pipe. It has been modified in various ways and at several places. The flue surrounds the air pipe nearly up to the steam chest of the engine, so that very little heat is lost. Radiation is also reduced to a small figure. Prof. Kennedy tells us: "The air was heated in passing through the stove up to 315° F. with a consumption of about 0·39 pounds of coke per I. H. P. per hour. As the admission temperature of the cold air was 83° only, this corresponds to an increase of about forty-two per cent. in the volume of the air and should, therefore (had the indicated efficiency remained the same), have been accompanied by a decrease of air consumption in the ratio of one divided by 1·42 or 0·70 inches. The air used in Paris is about eleven cubic feet of free air per minute per indicated horse-power. The ordinary practice in America with cold air is from fifteen to twenty-five cubic feet per minute per indicated horse-power. In Prof. Kennedy's experiments the engines were found to consume about fifteen cubic feet of air per minute per indicated horse-power without reheating.

The amount of fuel consumed during reheating is trifling. With the reheaters commonly employed it amounts to from one to two cents per horse-power per day. A more economical system of reheating will reduce these figures considerably. Prof. Kennedy says of the Paris reheaters: "It would not be difficult to design a more economical stove."

Fig. 2 illustrates a reheater in which the air is brought in contact with the fuel. The illustration is taken from a case which was put into actual service in connection with a rock drill. Immediately above the throttle valve and near the steam chest was placed an enlarged pipe fitting, in the interior of which, a little above the centre, was fixed a piece of wire gauze; above this gauze charcoal was thrown, some of it being in an incandescent state. The whole chamber was closed and the compressed air turned on. The air was thus brought in direct contact with the burning charcoal and was admitted to the drill cylinder extremely hot. With the consumption of a piece of charcoal an inch and a half in section and about two inches long, about two feet of hole were drilled. Instead of charcoal a substance called sestalit has been used with success, the advantage of sestalit being that it remains ignited for some length of time after the air has been shut off, and the products of combustion when discharged in a confined space are not objectionable.

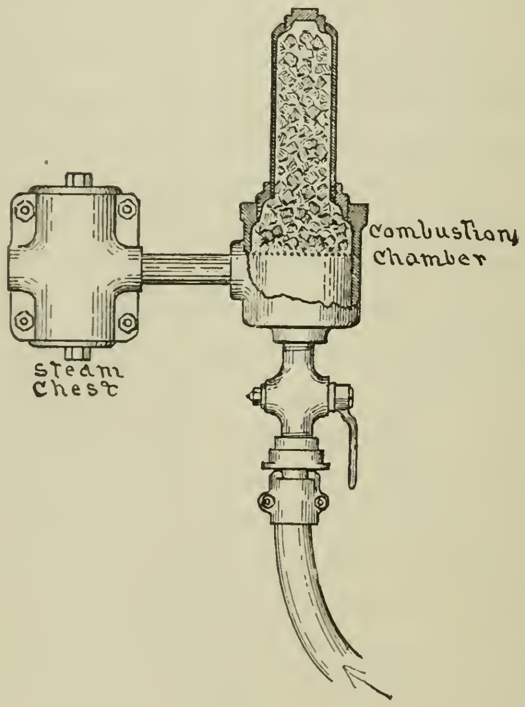


FIG. 2.

The system of reheating by internal contact is theoretically the most perfect, because the full value of the heat units in the fuel are transferred to the air. The air pipe is at the same time the combustion chamber and the flue, the products of combustion adding about five per cent. to the volume of the air, in addition to the large increase through expansion by heat. Box is authority for the statement that "When oxygen and carbon combine, the volume of the carbonic acid gas formed is nearly the same as that of the oxygen consumed; when, therefore, a combustible contains carbon only, the volume of gas in the chimney is the same as that of the air entering the fire, expanded of course to the volume due to the increased temperature, the oxygen consumed having been replaced by the same volume of carbonic acid gas. The nitrogen in the air is passive, passing through fire without chemical alteration. If the combustible contains water already formed and with which it is more or less saturated, vapor is formed from it and is added to the products of combustion."

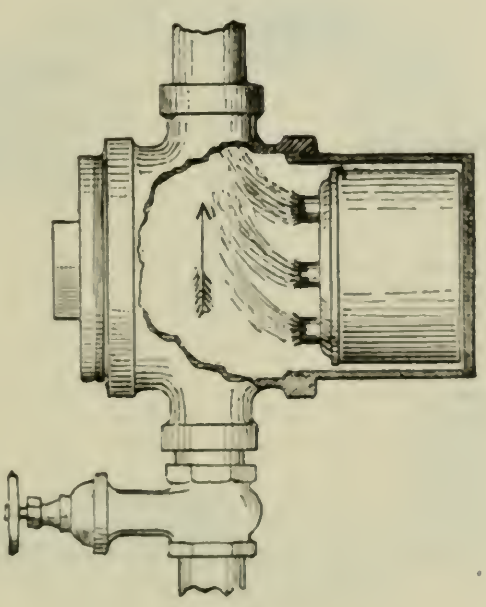


FIG. 3.

A simple reheater is shown in *Fig. 3.*

A common lamp is placed within the air pipe, the oil being supplied to the lamp by means of a hand pump. I first applied this system to one of the pipe lines on the new

Croton Aqueduct, using a common miner's lamp placed in a four-inch pipe.

Fig. 4 illustrates an electric reheater. The air compressor is shown at *A*, compressed air being conveyed through pipe *B* to receiver *C*, thence through a conduit *D* to a pump *E*, situated (say) a mile away. In the engine room with the compressor is a dynamo *H*, which serves to light the mine. At a point near the pump a resistance coil *F* is placed in a chamber communicating directly with the compressed air. This resistance coil is made of any highly refractory substance, which resists the passage of a current to such an extent that the electricity is converted into heat, and the heat is thus imparted to the compressed air. Such a reheater as this has many advantages. The entire absence of combustion makes it perfectly safe for inflammable mines, and the ease with which it is applied by simply opening or closing a switch recommends it. It is also a cheap device and has been applied recently in the shape of a simple coil of wire placed in an air pipe. The conversion of electricity into heat is an economical one, it being a well-known fact that a current of any potential, when intercepted by sufficient resistance, may be entirely absorbed and returned as heat. This is accomplished unit for unit, and as

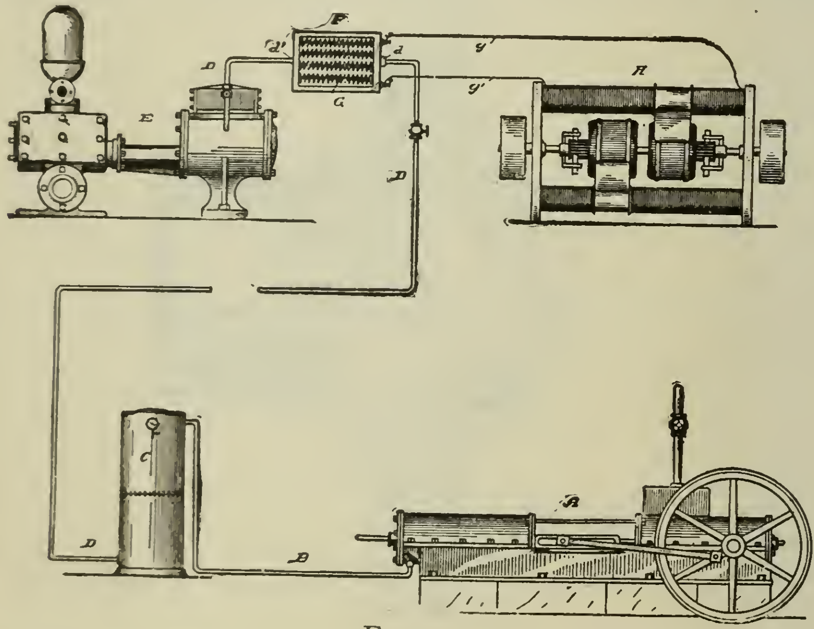


FIG. 4.

the loss in electric energy through transmission is low when compared with the shrinkage which takes place in compressed air, we here have a means by which the efficiency of the whole system may be increased by calling upon the electric wire to reheat the compressed air.

That it is theoretically possible to obtain from hot compressed air more power than was expended at the compressor, has been shown in *Fig. 1*. That this may not be confounded with perpetual motion but may be made clear, I have prepared a sketch, shown in *Fig. 5*.

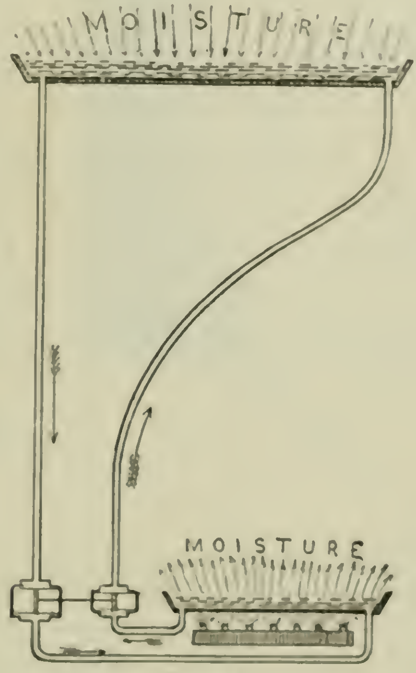


Fig. 5.

Sulphuric acid in its concentrated form, will when exposed in an open dish, absorb moisture from the atmosphere to the extent of about double its weight. A hypothetical assumption is made of a pump arranged to discharge sulphuric acid in the direction shown by the arrow to an open dish elevated (say) 100 feet. The amount of power necessary to discharge a certain quantity of sulphuric acid into this dish, is exactly equal to the power which the sulphuric acid is capable of giving out when falling back again, less the friction of the pump, leakage, etc. Now let us assume that the sulphuric acid in the open dish remained there long enough to absorb moisture from the atmosphere until its weight has been doubled; it will thus obviously have twice the amount of power in falling back again, and if the friction and leakage losses were not too great it will be capable of driving the pump, and of returning an equivalent volume of the concentrated acid to the dish. If the same acid is used over again the moisture must be driven out, and lamps are shown in the sketch provided for this purpose. The analogy between this hypothetical case of sulphuric acid and one of compressed air is, that, as with acid we may draw power from moisture which is contained in the air, so with compressed air may we draw upon the intrinsic heat energy of the atmosphere.

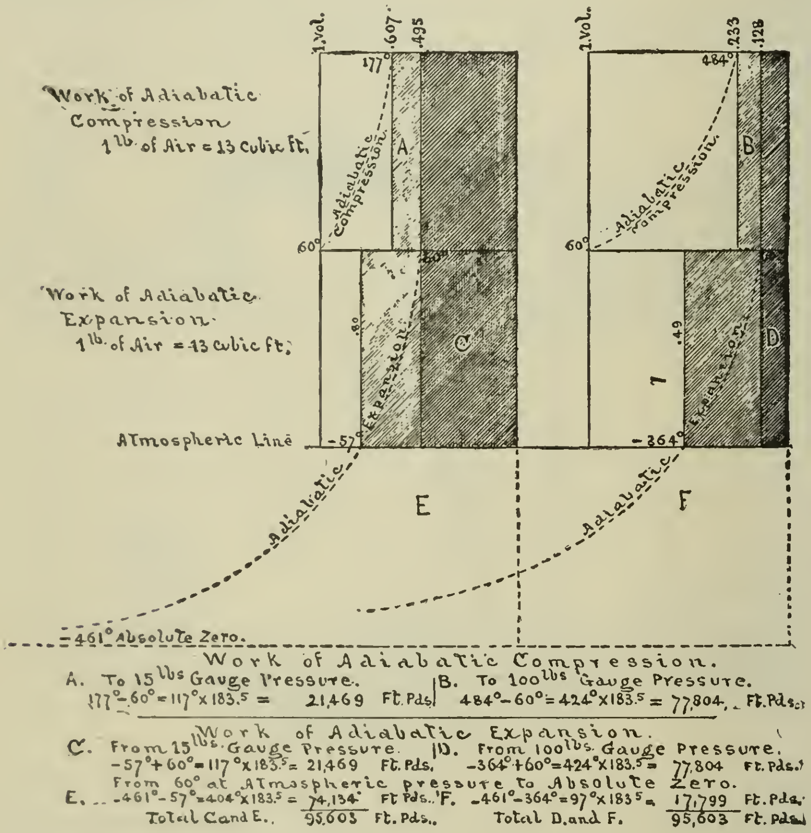

1 vol.
.607
.495
1 vol.
.233
.128
Work of Adiabatic Compression 1 lb. of Air = 13 Cubic ft.
177°
484°
Adiabatic Compression
Adiabatic Compression
A
B
60°
60°
Work of Adiabatic Expansion 1 lb. of Air = 13 cubic ft.
.80
.49
1
Expansion
Expansion
C
D
Atmospheric Line
-57°
-364°
Adiabatic
Adiabatic
E
F
-461° Absolute Zero.
Work of Adiabatic Compression.
A. To 15 lbs Gauge Pressure.
177°-60°=117°×183.5 = 21,469 Ft. Pds.
B. To 100 lbs Gauge Pressure.
484°-60°=424°×183.5 = 77,804 Ft. Pds.
Work of Adiabatic Expansion.
C. From 15 lbs. Gauge Pressure.
-57°+60°=117°×183.5 = 21,469 Ft. Pds.
D. From 100 lbs. Gauge Pressure.
-364°+60°=424°×183.5 = 77,804 Ft. Pds.
From 60° at Atmospheric pressure to Absolute Zero.
E. -461°-57°=404°×183.5 = 74,134 Ft. Pds.
F. -461°-364°=97°×183.5 = 17,799 Ft. Pds.
Total C and E. 95,603 Ft. Pds.
Total D. and F. 95,603 Ft. Pds.

FIG. 6.

These thoughts suggest the advisability of defining still further what is meant by intrinsic energy. Air being a practically perfect gas it will expand or contract in volume through a definite range in proportion to its temperature.

Experiments made with air at temperatures between the freezing and the boiling points of water, have given us the ratio of contraction of volume by reduction of temperature from which the absolute zero has been determined. The absolute zero of air is about — 461° F., and is that point at which any volume of air is reduced to nothing through expansion. In other words, the air may be said to be condensed at — 461°. We have therefore a base line which limits the power contained in any body of air.

Fig. 6 is a graphic diagram drawn for the purpose of illustrating the fact that the power which is contained in any body of air at a given pressure is dependent upon its distance in temperature above the absolute zero, and that there is as much power in a pound of air at fifteen pounds gauge pressure and 60° temperature, as there is in one pound of air at 100 pounds gauge pressure and 60° temperature. One pound, or thirteen cubic feet, of air at fifteen pounds pressure and 60° temperature, is represented by the space *C*. The available power in this air is 21,469 foot-pounds. By available power is meant the amount of power which can be utilized when this air is expanded adiabatically to atmospheric pressure. The diagram shows that when such pressure is reached the temperature will be — 57° F. There still remains in this air a certain amount of *intrinsic energy* and the diagram and figures show that this energy is equal to 74,134 foot-pounds. This added to the available energy gives us 95,603 foot-pounds, as the whole energy contained in one pound of air at fifteen pounds pressure and 60° temperature.

D represents one pound of air at 100 pounds pressure and 60° temperature. Its available energy is 77,804 foot-pounds, and its intrinsic energy is 17,799 foot-pounds or the total energy is 95,603 foot-pounds, which is exactly equal to the case just cited.

These figures prove the correctness of that thermodynamic law, which states that the power of any elastic gas is in direct proportion to its height of fall. So long as the temperature is above the absolute zero, there is as much power in the same body of air when expanded adiabatically from a moderate temperature to an extremely low one, as when expanded from a high temperature to a moderate one, and this offers to some extent a limitation to that system of reheating which increases the volume without at the same time increasing the pressure.

Fig. 7 is a diagram which illustrates a typical case in American practice, where air is admitted to a compressor at 60° and compressed adiabatically to 100 pounds pressure. It is then transmitted a sufficient distance to cool it down to 60° temperature and expanded back to atmospheric pressure, the temperature falling to — 364°. The conditions shown in the diagram are extreme and purely theoretical. In actual practice both compression and expansion are only approximately adiabatic.

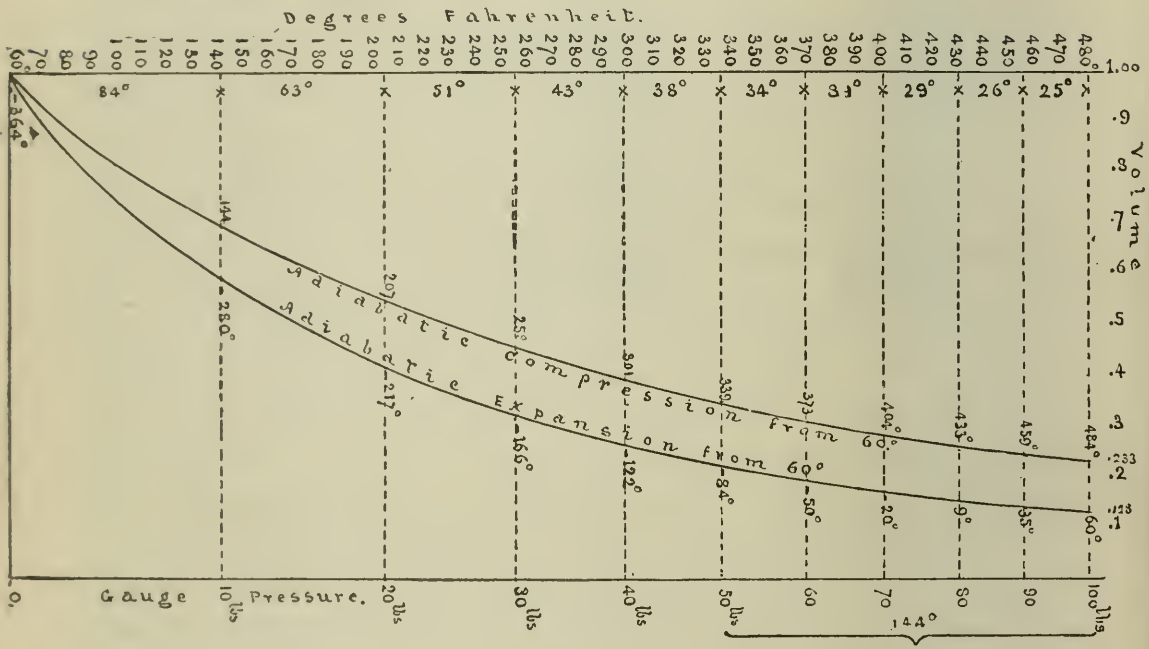
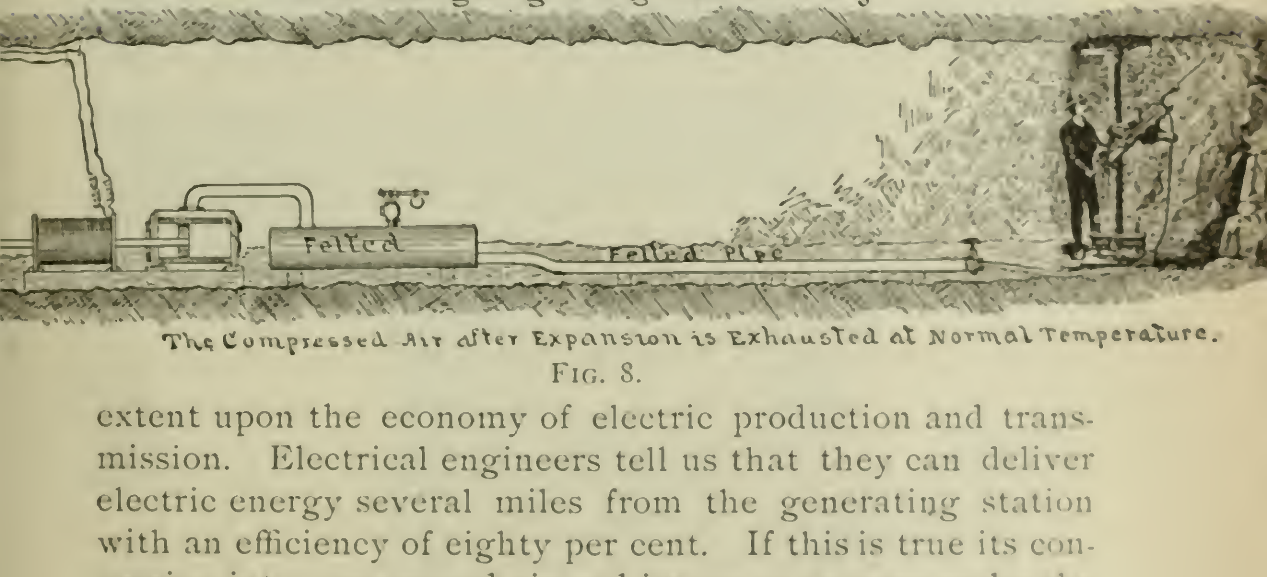


FIG. 7.

Fig. 8 illustrates an economical condition of compressed air use in mines and tunnels. The power is generated electrically and is conveyed by wire to a point within a few hundred feet of the heading where a rock drill is at work. By means of an electric air compressor hot compressed air is produced adiabatically, and is expanded adiabatically in the cylinder of the drill, following closely the economical conditions illustrated and described in *Fig. 1*. Such a state of things as this admits of an electric installation in the mine for the purpose of haulage, lighting, traction and pumping, to all of which uses electric energy has been successfully applied, and it gives us a means by which a compressed air drill may be successfully and economically operated at the heading. The air may be taken from the mine and when exhausted at the drill it serves to keep up a circulation in so confined a space as a heading, and as it is exhausted at atmospheric temperature there is no material change in the temperature of the mine. In some cases the air may be drawn through a flue from the outside, and thus through compression and expansion it will serve to ventilate the mine, as it does in the case of a compressed air installation. The economy of the system depends to its greatest

Combined Electric and Pneumatic System.
Showing Solenoid Air Compressor delivering hot air to Rock Drill and thus giving a high efficiency.



The Compressed Air after Expansion is Exhausted at Normal Temperature.
FIG. 8.

extent upon the economy of electric production and transmission. Electrical engineers tell us that they can deliver electric energy several miles from the generating station with an efficiency of eighty per cent. If this is true its conversion into compressed air and its use as a power under the conditions shown in the illustration, may be accomplished at a very moderate reduction of efficiency, because as is plainly seen the losses commonly incurred in compressed air service do not here take place. Electric rock drills are subject to many costly limitations. Thus far they have not been successful, and it is a serious question whether or not it is possible to accomplish the drilling of rock by the percussive principle (which is the only true one), by an electric engine which will be equal in weight, in price and efficiency to an air engine. The weight of a rock drill is one of its most conspicuous limitations, and from every basis of theory and practice a compressed air percussive engine will weigh less than half that of an electric one of the same power. An electric drill is made of copper which cannot compete in price with iron, and the durability of the apparatus is apparently in favor of the air drill. But as mines are likely to be lighted by electricity, and as there are many conditions of work favoring electric transmission for other purposes, we here have a means by which all the advantages of the air drill are maintained in an electric installation.

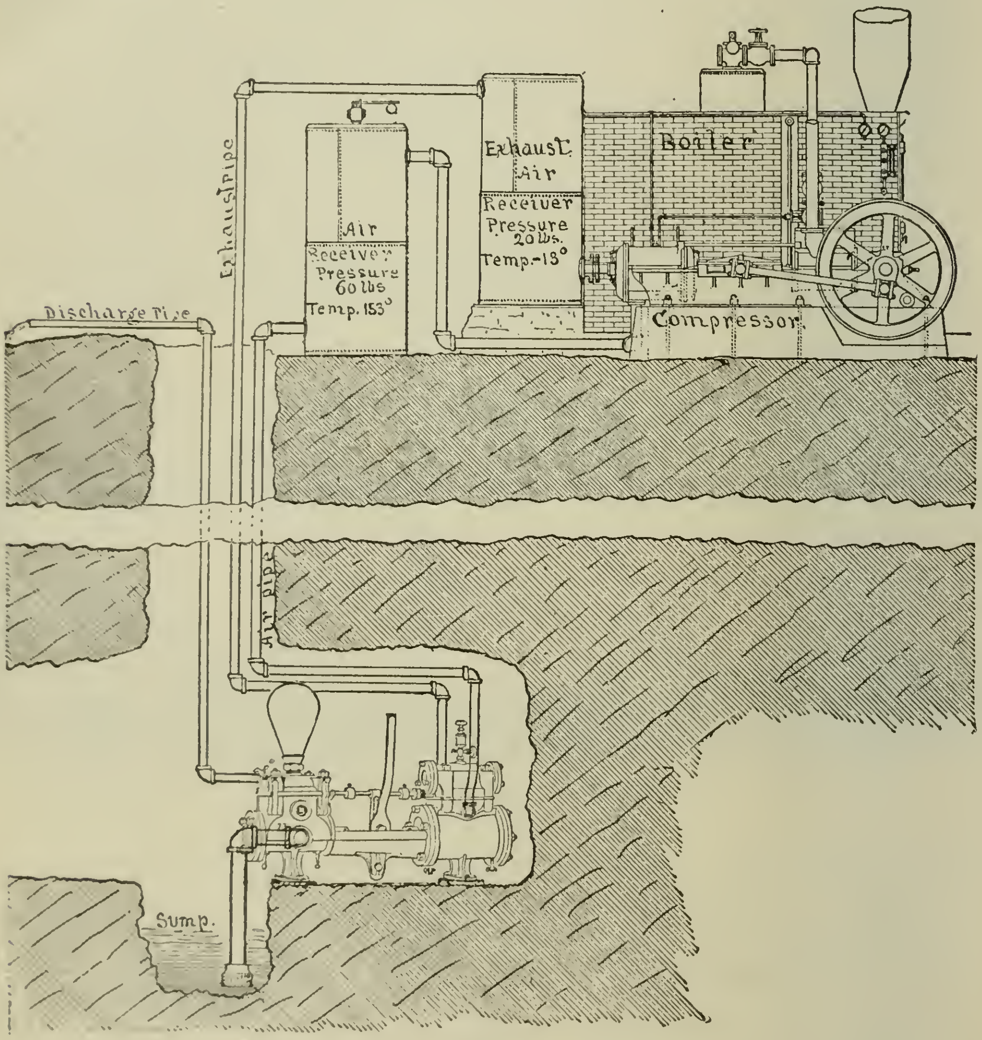


Fig. 9.

Fig. 9 illustrates what may be called an endless chain of pneumatic power. An air compressor draws its supply of air from a receiver in which there is a pressure of twenty pounds. The air is compressed to sixty pounds, and is carried down a shaft and used to drive a pump. The exhaust of the pump is returned to the initial air receiver; and thus the same air is used over and over again, all of the exhaust pressure being utilized. As pumps usually exhaust at pressures from twenty to fifty pounds, a large saving is effected in this alone.

When starting, it is simply necessary to open a valve on the initial air receiver until a pressure of sixty pounds has been reached in the secondary receiver; the valve is now closed and the work goes on. The economy of this system is apparent. The heat of compression is converted into work in the pump, and a very low temperature of air is maintained. The economy of low initial temperature in air compression has been fully set forth in a diagram which I have published in *Compressed Air Production*, and a power diagram of such a system as this indicates several other economical points, notably the admission of compressed air instead of free air through the inlet valves, which serves to reduce the heat loss during compression and to equalize the resistance strains in the engine.

Fig. 10 illustrates in contracted form a complete pneumatic installation comprising boiler, air compressor, air receiver, air injector, supplementary air receiver, pipe for transmission, reheater and air engine. The reheater and air engine should be considered as situated from 1,000 feet to several miles from the compressor.

It will be observed that atmospheric air is drawn in the piston inlet tube of the compressor at 60° temperature. It is compressed adiabatically; that is, without any provision for cooling during compression, and in this way all of the power expended in the steam cylinder is converted into heat, which remains as power in the air. Perfect adiabatic compression, as previously stated, cannot be attained because of the absorption of heat by the metallic surfaces, radiation, etc. For the sake of illustration, however, the figures are given at adiabatic compression.

Now, we have seen that, if all of this heat can be utilized, it will return 100 per cent. in power, less such small items as friction, leakage, etc., and the purpose of this sketch is to call attention to a means by which at least a large part of this heat may be saved, and not wasted by radiation into the atmosphere or by absorption in water. An air injector is located between two air receivers, and the highly compressed or the highly heated air from the first receiver is admitted through the nozzle of this injector, and is thus converted into high velocity inducing free air from the atmosphere, and discharging an increased volume at a reduced pressure and temperature into a secondary receiver. For the sake of illustration, the pressure in the first receiver is taken at 100 pounds and is reduced to fifty pounds.

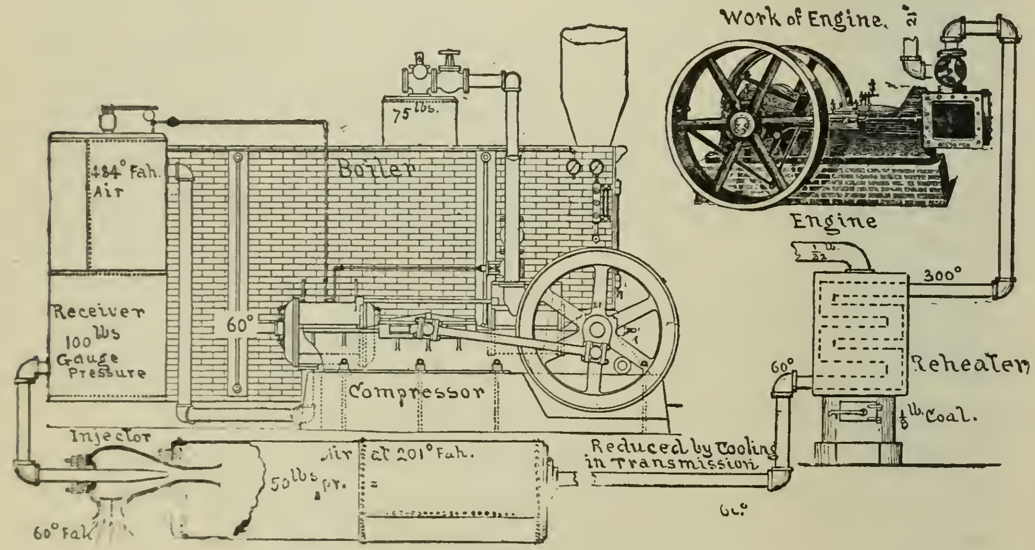


FIG. 10.

This air injector has been tried with success though the experiments have not gone far enough to determine to what extent it will effect a saving in the production of pneumatic power. It has been found that with a pressure of eighty pounds in the first receiver, the injector will work discharging and inducing free air into a second receiver in which is maintained a pressure of sixty pounds. This difference of pressure may obviously be modified by the shape of the nozzle, sizes of pipes, etc., and it is probable that the injector may be made to work at a difference between the two pressures of only ten pounds.

The principle is similar in many respects to that of the boiler feed injector about which there are so many mysteries. We know that not only is it possible to feed a boiler through an injector which takes the steam at a pressure lower than the boiler pressure, but the *exhaust injector* is a practical success. That we may exhaust steam from an engine and, by means of such exhaust, feed water to the boiler which supplies the engine with live steam, is indeed a mystery, and it is fair to assume that equally valuable and surprising results may be obtained from the induced air injector.

Mr. Green, the inventor of the Green system of ventilation, which is used on Trans-Atlantic steamers, is now conducting experiments looking toward the ventilation of the Forty-Second Street tunnel, New York, by means of air induced through an injector. His experiments have shown that one volume of air when passed through the nozzle of an injector at a pressure of five pounds, will induce thirty volumes of free air; that is, a volume efficiency of thirty to one. Mr. Green measured his air by means of a meter.

His conditions were similar to that outlined in the sketch, differing only in degree, and while it is not expected that so large a percentage of volume in free air may be induced, yet on the basis of figures alone, when compared with Mr. Green's experiments, we might expect from three to five volumes.

The velocity with which compressed air is discharged through a nozzle does not differ materially at pressure of fifteen pounds and over. The actual velocity with which compressed air at five atmospheres is discharged through a short pipe, is 658 feet per second, and at ten atmospheres the velocity is 649 feet per second. This is because high pressure air is more dense than air at low pressure, and just in proportion as the density increases does its resistance to movement increase. This is one of the limitations to the pneumatic dynamite gun. They started on about 500 pounds pressure and fell short of the mark. It appeared that it was only necessary to increase the pressure to increase the range, but the limitations were soon discovered.

With air discharged through an injector nozzle at a velocity of 650 feet per second, it is easy to understand that free air will be induced and discharged with it into a secondary receiver. The nozzle should be constructed so as to offer the maximum amount of contact for the minimum volume of discharge, and such a nozzle has been built by Mr. Green; it takes hold of the induced air not only on the outside but also directly in the centre or core of the jet.

This is not a case where something is sought from nothing. The hot compressed air is converted into high velocity and thus the heat of compression is utilized. Were it not utilized in this way it would simply be discharged into the atmosphere by radiation, which is the usual practice in long-distance transmission in America.

Compressed air cannot be produced isothermally. In spite of the best system of injection combined with water jackets and a complicated apparatus, there will still be the heat of compression influencing pressure during compression. Compressors have been made which show cold discharge pipes and passages, and cold air in the receiver, but the largest part of this reduction in temperature has taken place *after* compression. If we cannot keep down the heat during compression, and if it be true that in keeping it down even to a reasonable extent, large complications are involved in the machinery, why not let it be produced and so simplify the apparatus, then let this *hot high pressure expanded air* be discharged through one or two injectors until its temperature has been reduced to a point *approximately what it will inevitably reach during transmission*, and thus *we have converted the heat of compression into air volume.*

The reheater shown in the sketch is little more than a common stove, the air pipes passing through the furnace. This saves *volume* of air only, it cannot increase the pressure. The engine which is driven by the compressed air should be provided with an automatic cut-off, and to insure economy it should exhaust at atmospheric pressure. It is obvious that when exhausting at atmospheric pressure it will also exhaust at a comparatively high temperature, unless the air is first admitted at a pressure sufficiently high to admit of early cut-off and complete and economical expansion. This points to economy under some conditions by using high pressure air in an engine which works in connection with a system of reheating, and it also points to the highest economy which will be shown by that system which follows the conditions shown in the sketch, but which reheats or rather explodes the compressed air *behind the piston of the air engine after admission and cut-off.* This principle has been verified to some extent in certain oil and air engines, notably the Priestmann and Grigg, which have recently been brought to the attention of engineers.

CELLULOSE OR WOOD FIBRE.

BY PROF. S. P. SADTLER.

[*A lecture delivered before the Franklin Institute, February 1, 1892.*]

The percentage composition of dry and ash-free cellulose corresponds to the formula $(C_6H_{10}O_5)_n$. It is, therefore, placed in the class of polysaccharides, to which starch and many of the gums belong. It must be understood, however, that this applies to the purified cellulose after the extraction from admixture with other associated principles. This extracting is done by exposing the moist vegetable tissue to the action of chlorine gas or of bromine water in the cold, and subsequent boiling in dilute ammonia, repeating this treatment until the alkaline solution no longer dissolves anything from the tissue or fibre. With many plants, such as cotton, flax, hemp, etc., this reaction, while requiring time and repeated action of the reagents, can be effected with thoroughness. With others such as jute, straw and compact wood the extraction is combined with greater difficulty, and when accomplished yields a product differing in important particulars. It is also often a very difficult matter to draw the line between *mixtures* and combinations of cellulose with non-cellulose constituents of either fibres or tissues.

The following compound celluloses Cross & Bevan, who have made an especial study of this subject, consider sufficiently characterized to warrant special description under class names:

Pecto-celluloses.—Resolved by hydrolysis (with alkalies) into pectic acid and cellulose. Type—raw flax.

Ligno-celluloses.—Resolved by chlorination into chlorinated derivatives of aromatic compounds, soluble in alkalies and cellulose. Type—jute.

Adipo-celluloses.—Resolved by oxidation (with nitric acid) into derivatives similar to those from the oxidation of the fats and cellulose. Type—the cuticular tissue of leaves and fruit.

The pure cellulose obtained from cotton or linen fibre retains the microscopic features of the raw fibre and thus readily betrays its origin. It is insoluble in all simple solvents, but is first swelled and then dissolved by an ammoniacal solution of cupric hydrate. As pure cellulose is comparatively inert the reactions which would serve for its identification are few. One of them may be noted, viz: its reaction with iodine. This reaction differs from that of starch in requiring for its determination the presence of an auxiliary reagent of dehydrating power, such as sulphuric or phosphoric acid or zinc chloride. Such a solution containing iodine dissolved in potassium iodide admixed with zinc chloride, colors cellulose instantly a deep blue or violet.

Not much light on the constitution of the cellulose molecule is gained by studying the action of reagents upon it, but many very interesting and technically important derivatives have been obtained. One of the most interesting of these derivatives and of considerable technical importance is the oxycellulose, which is obtained by the action of weak oxidizing agents upon cellulose. That cotton fibre exposed too long to the influence of bleaching powder solution, or even repeatedly exposed to air and light, became weakened or "tendered," had been known for a long time before it was ascertained that this was due to the formation of an oxycellulose, which differed in many of its properties from the original cellulose. The oxycellulose attracts the basic coloring matters from their solutions, and is dyed to full shade and fast color without previous mordanting. It also has a most remarkable attraction for vanadium compounds which it takes up from the most dilute solutions.

In many reactions, moreover, it bears much analogy to the lignin of the Ligno-celluloses.

Probably the most important of the derivatives of cellulose are the nitrates obtained by allowing strong nitric acid or a mixture of nitric and sulphuric acids to act upon cellulose. Taking the doubled formula $C_{12}H_{20}O_{10}$ for the cellulose, the highest nitro derivative formed is the hexanitrate $C_{12}H_{14}O_4(NO_3)_6$, the essential constituent of the true gun-cotton. This compound is insoluble in alcohol, ether or mixtures of both, as well as in methyl alcohol. Acetone alone dissolves it very slowly.

This most explosive variety of gun-cotton, according to Eder, is not produced by mixtures of nitre and sulphuric acid but only by using the strongest nitric and sulphuric acids, in which the cotton is immersed at a temperature not exceeding 10° C. (50° F.) for twenty-four hours. The pentanitrate $C_{12}H_{15}O_5(NO_3)_5$ is best prepared according to Eder's method by dissolving the hexanitrate or explosive gun-cotton in nitric acid at 80°–90° C. (176°–194° F.) and precipitating by concentrated sulphuric after cooling to 0° C. (32° F.). After washing the precipitate with water and then with alcohol it is dissolved in ether-alcohol and again precipitated with water. This nitrate, of which small amounts may be formed in the manufacture of explosive gun-cotton, is soluble in the mixture of ether-alcohol. The tetra and trinitrates $C_{12}H_{16}O_6(NO_3)_4$ and $C_{12}H_{17}O_7(NO_3)_3$ are generally formed together when cotton is nitrated with a more dilute nitric acid, at a higher temperature and for a much shorter time than that given for the hexanitrate. This mixture constitutes collodion pyroxyline and is soluble in ether-alcohol, acetic ether, acetic acid or methyl alcohol. The dinitrate $C_{12}H_{18}O_8(NO_3)_2$ always results as the final product of the action of the alkalies upon the higher nitrates.

and also from the action of hot, somewhat dilute nitric acid on cellulose. It is the lowest derivative attainable, a mononitrate having not as yet been formed.

The technical uses of these nitrated derivatives of cellulose are very important. An extremely interesting lecture was delivered in this hall a few weeks ago by Professor Munroe, of the Naval War College, of Newport, in which the characters of the explosive gun-cotton were discussed and its properties narrated. An equally interesting one might be made upon the now numerous applications of the lower nitrates, constituting as they do the bases of collodion or wet-plate photography, of the manufacture of celluloid and of pyroxyline varnishes. We will, however, pass on at present to note the chemical characters of the compound celluloses, the classification of which I have already given.

The first class, the pecto-celluloses, as the name indicates, are compounds yielding pectic acid when the cellulose is liberated from its combination. Thus, in the treatment of raw flax, the retting and bleaching processes are designed to break up this natural compound, the soluble pectic acid being washed away. Dilute alkalies effect the same result and this treatment is the one often employed in plant analysis to isolate the cellulose.

The third class, the adipo-celluloses, includes the cuticular tissue of fruits and of fibres such as cotton, straw, esparto, etc. Under the action of boiling nitric acid, these tissues are resolved into cellulose on the one hand and a series of fatty acids or products of their decomposition, suberic and adipic acids, such as are obtained from cork tissue, whence the name adipo-celluloses for the class.

In the second class, the ligno-celluloses, we have included by far the most important and interesting of the compound celluloses, viz: the different forms of woody tissue and lignified fibres, such as jute. The last-mentioned fibre indeed shows so clearly the nature of the combination between cellulose and what is termed lignin, that a study of it has thrown much light upon the characters of the whole class, and has aided chemists in getting a clear understanding of the methods for isolating cellulose from its combination in the compact woods, which are now so largely used as a source of paper-making material.

Jute is a compound of twenty-five per cent. non-cellulose or lignin and seventy-five per cent. cellulose. The non-cellulose constituent is more readily attacked by reagents than the cellulose. Thus if the compound fibre be first boiled with a weak solution of an alkaline hydrate and then exposed to moist chlorine, the non-cellulose is attacked and on subsequent boiling with sodium sulphite solution the decomposition into cellulose and soluble non-cellulose derivatives is complete. Dilute nitric acid also attacks the non-cellulose, resolving it into soluble products and can be used to isolate the cellulose, but it attacks the latter somewhat also.

Wood consists of about two parts of cellulose in admixture with one part of lignin. Very characteristic color reactions are obtained by moistening any of these lignin-containing compounds with phenols, such as phloroglucin, and hydrochloric acid. They are also colored carmine by an alcoholic solution of pyrrol and deep yellow by solution of aniline sulphate. They take up organic dye-colors very much like the oxycellulose before referred to. Among the decomposition products of the lignin or non-cellulose have been found vanillin, coniferin and several wood-gums allied to gum arabic. Indeed a recent writer places lignin, because of its composition, amongst the class of gum resins. He has found in the products of the sulphite process for preparing wood-pulp as well as in those of the soda process, transparent resinous substances which are very similar in reaction to the arabic acid of natural gum arabic. He therefore is led to offer the following theory of these two well-known chemical wood-pulp processes. If wood is boiled under great pressures with caustic soda the lignin is decomposed. The gummy matters, resins and phenols, are dissolved and the volatile compounds, *e.g.*, terpenes, etc., escape. Cinnamic aldehyde and vanillin polymerize and coniferin is decomposed. It is well-known that sulphurous acid has a decomposing or polymerizing effect upon many groups of organic compounds. In the sulphite process, it first decomposes lignin and then the free arabic acids decompose the sulphite of lime, hereby forming the calcium salt of the arabic acid which remains in the solution while the free sulphurous acid escapes. The author is of opinion that the sulphite process is in the main hereby explained. The terpenes and aldehydes mostly polymerise and escape, together with the other volatile aromatic compounds of the woody matter as well as the sulphurous acid, whilst the non-volatile substances, *e.g.*, the resins, are left, parts of which remain as the calcium salts of the resin acids."

The technical applications of this class, as said before, are already of enormous importance. The increasing use of wood-pulp as a paper-making material is the explanation of this. We will now take up for brief notice this most important of the cellulose industries. Wood, as before stated, contains cellulose in combination with lignin, together with mineral salts and some little coloring resin. The proportion of these constituents varies somewhat in different varieties of wood, as shown in the accompanying table from Müller.

	Birch.	Beech.	Lime.	Pine.	Poplar.
Cellulose, ...	55·52	45·47	53·09	56·99	62·77
Resin, ...	1·14	0·41	3·93	0·97	1·37
Aqueous extract, ...	2·65	2·41	3·56	1·26	2·88
Water, ...	12·48	12·57	10·10	13·87	12·10
Lignin, ...	28·21	39·14	29·32	26·91	20·88

The practical problem now is to extract the cellulose in such condition as to enable it to answer the requirements of the paper-maker, viz: strength and length of fibre, which give it felting power, and for finer papers freedom from resinous and coloring impurities, such as would prevent its use as a mixing ingredient or substitute for linen cellulose.

We divide the wood-pulp methods into the two great classes of mechanical and chemical.

In the mechanical wood-pulp process, the wood, cut into blocks, is pressed against revolving grindstones, the surface of which has been roughened by the cutting of grooves.

The wood is placed so that the revolving stone shreds or tears the fibres laterally and not transversely to the line of the fibre, while a stream of water kept flowing over the stone, washes off the fibre as rapidly as it is loosened. Even then the fibres are relatively short as compared with those obtained by the chemical processes. The pressure of the blocks of wood against the stones is maintained either by screws capable of adjustment as required, or by hydraulic pressure. The pulp as washed off the stones is passed over screens, which retain larger fragments to be ground again and allow the finer pulp to pass through and this is then farther sorted by sieving.

The quality of the mechanical pulp is improved by steaming the wood thoroughly before shredding, so that the wood being softened a longer fibre may be torn off. Such mechanical wood-pulp is made and comes into commerce under the name of "steamed pulp." The specimens shown are from the Androscoggin Pulp Company, of Brunswick, Me., and are mixed spruce and pine. The steaming of the wood is continued for eight to ten hours at a pressure of about forty pounds, and drip valves are attached to the upright boilers used, so that the wood is not soaked in hot water but exposed to the action of steam only.

Paper made from mechanical wood-pulp is very liable to become discolored by the action of air and light, the lignocelluloses being much more readily acted upon than the celluloses isolated from them. This fibre is, moreover, of very slight felting power on account of its shortness, but it is cheap and is used in large amounts for filling material, or it may be exclusively for cheap newspapers.

In the preparation of chemical wood-pulp, on the other hand, the lignin or non-cellulose constituents of the wood are decomposed and eliminated, so that a relatively pure cellulose remains, in amount varying with the process employed and the kind of wood taken. The processes that have been found applicable for this decomposition of lignin and separation of cellulose are classified as follows by Cross & Bevan, in their *Paper-making*:

VIEW OF THE CHEMICAL PROCESSES FOR DISINTEGRATING WOOD.

(1) *Aqueous alkalies.*—Hydrolysis aided by alkali directly, also indirectly by combination with products of resolution. (Watt and Burgess, 1853; Houghton, 1857.)

(2) *Solutions of alkaline sulphides.*—Hydrolysis, aided by alkaline bases directly and indirectly by combination with the products. Reversal of hydrolysis lessened by presence of reducing agent. (Jullion, 1855; Blitz, 1883; Dahl, 1884.)

(3) *Water.*—Hydrolysis, aided by acids formed from the wood. Limit of action determined by reversal of hydrolysis, *i. e.*, dehydration aided by oxidation. (Fry, 1867.)

(4) *Water, together with neutral sulphites.*—Simple hydrolysis. Products removed from sphere of action by combination with base and sulphite. Oxidation prevented by presence of sulphite. (Cross, 1880.)

(5) *Aqueous acids.*—*a.* Oxidizing and hydrolytic. Nitric acid. (Coupier and Mellier, 1852; Barre and Blendel, 1861.) Nitro-hydrochloric. (Orioli, 1865.)

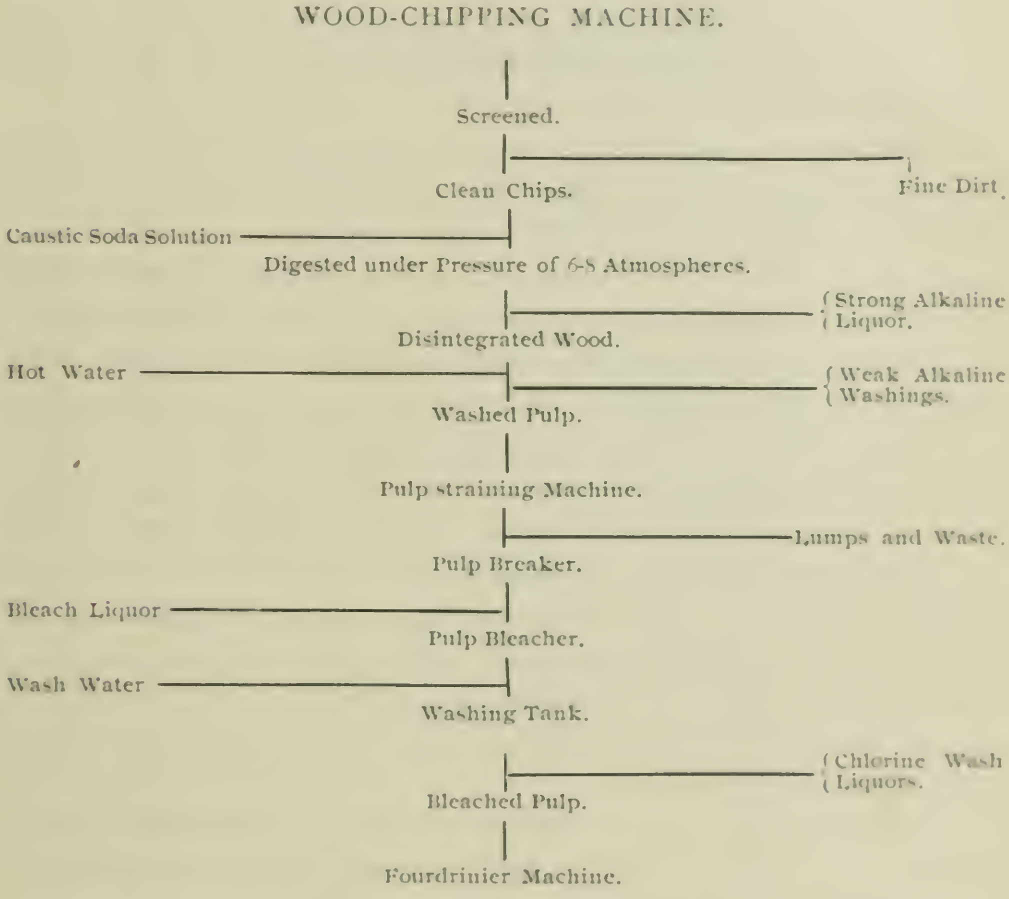
b. Simply hydrolytic. Hydrochloric acid. (Bachet and Machard, 1864.)

c. Reducing and hydrolytic. Sulphurous acid. (Tilghman, 1866; Pictet, 1882.)

(6) *Bisulphites.*—Hydrolysis aided primarily by sulphurous acid and secondarily by combination of products with bisulphites, also by prevention of oxidation. (Tilghman, 1866; Mitscherlich, 1874; Ekman, 1881; Franke, 1881; Graham, 1882.)

The processes in practical operation at the present time have narrowed down to those under two of these headings, viz: soda pulp processes and "sulphite," or more correctly bisulphite pulp processes.

The first of the soda processes was that of Watt & Burgess, and this, with some modifications, is still in successful use to-day. It depends, as was mentioned before, upon the fact that the lignin is decomposed by the caustic alkalies under pressure, and the products of the decomposition go into solution. Its drawbacks are that under the conditions needed to complete the disintegration of the wood, the cellulose portion itself is attacked, and hence, the yield of finished pulp is smaller than by some other processes. And when the regeneration of the soda was incompletely carried out, as was often the case, the process was an expensive one. Great improvements have been effected in this matter, however, and with the present high percentage of recovery, the process makes a better showing. A diagram, showing in graphic form the several stages of the Burgess soda process as carried out in this city, is shown.



Of the sulphite processes mentioned in the diagram already given, that which is most generally employed in this country is the Mitscherlich, while in England the processes of Ekman and Franke, as modified by Partington, have been tried in addition. The Mitscherlich and the Franke processes use bisulphite of lime, while the Ekman process takes a bisulphite of magnesia. The sulphurous oxide, of course, is produced by the burning of sulphur or pyrites, and this gas, after being cooled, is passed into milk of lime, placed in large tanks, which are used either singly or connected in series for more complete absorption. This bisulphite liquor then acts upon the chips in closed boilers or "digesters" under a pressure of ninety pounds, for some nine to ten hours. A longer boiling at somewhat lower pressure is also used in some cases.

Of the side-products, shown to the right in the diagram, the strong alkaline liquor is run to the evaporator to be evaporated, calcined, dissolved and causticized for renewed use; and the chlorine wash liquors are used in dissolving chloride of lime for fresh bleach liquor.

After the completion of the boiling, the mixture is blown out into large vats provided with drains in the bottom to allow of the escape of the spent liquor. It is then thoroughly washed, mixed with water and pumped onto screens to allow of the removal of chips or impurities. The screened pulp is then felted and is ready for delivery as unbleached pulp. In this condition it is very prone to discoloration, usually turning pink and finally brown when exposed to atmospheric influences for a time. The reason is very simple from a chemical point of view. The reducing action of sulphurous acid, it is well known, is always a transient change and is in time overcome by the atmospheric oxidation following exposure to air and light. If, however, the well-washed pulp is thoroughly bleached by an oxidizing agent like chloride of lime, the pulp is no longer affected by atmospheric influences.

Sulphite pulp in the United States is prepared chiefly from spruce wood, and when properly bleached gives an almost pure cellulose, white and of strong fibre.

The wood-pulp production of the United States more than trebled during the decade between 1880 and 1890, and now employs between 200 and 300 factories, of which the larger number run, of course, on mechanical wood-pulp, although the chemical wood-pulp processes are gaining ground relatively faster, and are at present coming into greater favor.

OBITUARY.

CHARLES J. SHAIN.

Charles J. Shain, for nearly half a century an active member of the Institute, and for several years a member of its Board of Managers, recently died at Atlantic City, N. J., where, for some time previous to his death, he had made his permanent home.

The subject of this sketch was born in Philadelphia, October 27, 1822. He was educated at private schools, and as a minor was apprenticed to William J. Young, the founder and head of the then principal establishment in Philadelphia engaged in the manufacture of mathematical instruments. In 1850, he formed a co-partnership with Joseph Knox (one time foreman in the Young establishment), under the firm name of Knox & Shain, manufacturers of engineering and telegraphic instruments. This firm continued in active business until the death of Mr. Knox, in 1877, and became widely and favorably known throughout the country, their instruments taking high rank in the estimation of civil engineers.

It may be of interest to record the fact that the instruments used by the late Edgar Thompson, in the first survey of the Pennsylvania Railroad, were those of Knox & Shain.

Upon the severance of this long-time connection, by the death of his associate, Mr. Shain retired to private life. His connection with the Franklin Institute dates from his election to membership, in the year 1843, and was continued uninterruptedly to the time of his death. He was elected to the Board of Managers in 1884, and served until 1887, when, on account of his removal from the city, he declined a re-election. He was warmly interested in the Institute, and contributed freely of his time and special knowledge to the furtherance of its work. He died at Atlantic City, on November 23, 1891, of Bright's disease, in his 70th year.

His unvarying courtesy and amiability greatly endeared him to his fellow-members and officers, by whom his loss is sincerely deplored.

Mr. Shain leaves a widow and two sons to survive him: Dr. Francis W. Shain, for some years surgeon in the service of the Red Star Line and at present a practising physician in Jersey City, and Chas. D. Shain, district manager for the Edison Company, of New York. W. H. W.

EUGENE H. COWLES.

Eugene H. Cowles, who died at El Paso, Tex., on April 21, 1892, at the early age of thirty-eight, had attained a world-wide recognition by the scientific world for his inventions in connection with the manufacture of aluminum. These inventions, in the origination and development of which he was assisted by his brother, Albert H. Cowles, involved in principle the application of the heating action of the electric current for the reduction of aluminum and other metals, and are too well known to need extended reference in this place. It will suffice to allude to the fact that the result of the Cowles inventions was a revolution in the aluminum industry as profound as that caused by the earlier work of Deville. The process enabled the inventors to produce the alloys of aluminum vastly more cheaply than had hitherto been possible, and at once a large demand for these products was created. To carry out their process effectively, the Messrs. Cowles were compelled to do a large amount of pioneer work, in connection with the design of dynamos of large power, the control of currents of hitherto unprecedented magnitude, the manufacture of carbon electrodes of great size, and to work out, in the face of many difficulties and discouragements, many details of operation that now seem comparatively easy, but for which at that time there were no precedents to build upon. For all this pioneer work and for the successful introduction of their process in this country and in Europe, the brothers Cowles deserve the highest praise.

The first institution of learning to take note of, and to recognize the importance of the inventions of the Cowles brothers, was the Franklin Institute. Shortly after the first public announcement of the Cowles process, an invitation was extended to the inventors to read a paper on the subject before the Institute, which was accepted by the subject of this sketch. This paper was presented at the stated meeting held January 20, 1886, and, under the title, "The Production of Aluminum and its Alloys in the Electric Furnace," appears in the impression of the *Journal* for February, 1886. It was an able and comprehensive treatment of the subject, and reflects the highest credit on its author.

The success with which the efforts of the inventors to secure the general adoption of their process was crowned, sufficiently demonstrates that their faith in its commercial and technical value was neither misplaced nor exaggerated.

The Franklin Institute, in recognition of the merits of the invention of the Cowles brothers, awarded to them, in 1886, the highest honor in its gift—the Elliott Cresson Medal—"for their invention of a new process in the metallurgical arts for the reduction of refractory substances," and recommended the award of the John Scott Legacy Medal and Premium to the inventors, "for their electric smelting furnace," which recommendation was subsequently confirmed by the Board of Directors of City Trusts.

Subsequent events demonstrated that the judgment of the Institute in estimating the value of these inventions so highly was fully justified. The late Mr. Cowles never forgot the early appreciation of his work by the Institute, and cherished the tokens of its recognition with affectionate regard.

His untimely death before he had yet reached the measure of years when those better equipped with physical endowments are in the prime of their powers for usefulness, is a loss which all friends of science will learn with sincere regret.

W. H. W.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, April 19, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Professor Henry Trimble read a paper on "Chestnut-bark Tannin." This paper gives the results of an investigation which forms the second and final part of a research to determine whether any differences exist between the tannin extracted from the wood of the tree on the one hand and the bark on the other. The results of the investigation of the tannin from the wood have already been published by Prof. Trimble in a former paper read before the Section. The results formed a subject of a brief discussion, and the paper was submitted for publication in the *Journal.*

A sample of the tannin was exhibited by the author.

A brief communication from Mr. Chas. E. Ronaldson, M.E., on "The Influence of Bottles upon Wines," was read and discussed by the Section. The same related principally to the progress made in the United States by glass manufacturers in producing glass of proper composition for the purpose named.

The Section then adjourned. WM. C. DAY, *Secretary.*

CHESTNUT-BARK TANNIN.

By Henry Trimble.

[*Read at stated meeting of the Section, held Tuesday, April 19, 1892.*]

In the manufacture of chestnut extract the bark and wood are used together, the latter naturally exceeding the former in amount, as well as in yield of extract.

It has been thought desirable to determine if there exists any differences in the character of the tannins from these two parts of the tree, and the results of an investigation of that from the wood were published in this *Journal*, **132**, p. 303.

The material in this case was obtained from a tree thirty years old, cut in August; the bark was immediately removed, air dried and powdered.

The total tannin was found to be 7·31 per cent. The wood yielded 7·85 per cent. The other important constituents in the bark were found to be in per cent., 1·09 of resin, 3·06 of mucilage, 1·35 of glucose, 10·00 of moisture, 4·71 of ash and 45·44 of cellulose.

The tannin, as extracted by commercial ether, was much darker in color than that similarly prepared from the wood, but an equally light-colored product was obtained by first precipitating in fractions with lead acetate, and then further treating the middle and most abundant one with salt and acetic ether. The aqueous solution of this portion, after removal of lead by hydrogen sulphide, when saturated with common salt, separated a dark-colored portion which rose to the top, and was easily removed in one mass after standing twenty-four hours. The remaining light-colored solution was agitated with acetic ether, the latter separated, and, after removal of the solvent under reduced pressure, a light-colored product was obtained. This was then dissolved in water, filtered and the solvent distilled off under reduced pressure; it was then dissolved in ether, filtered and again dried in a vacuum at the temperature of a boiling water-bath.

The product was a light, almost white, porous mass of a reddish-brown shade, which was completely and readily soluble in water and the other usual solvents, and in all other respects corresponded with the chestnut-wood tannin described in the previous paper, as well as with gallotannic acid. It did not give any reaction for glucose, from which compound it was rather more easily purified than the product from the wood.

The average of two closely-agreeing combustions gave the following percentages, with which are given those from the tannin of the wood, for comparison :

	Chestnut-bark Tannin.	*Chestnut-wood Tannin.*
C,	52·42	52·11
H,	4·67	4·40
O,	42·91	43·49
	100·00	100·00

The conclusions to be drawn from this work are that the tannins from chestnut bark and wood are identical, and, although ultimate analyses show high percentages of hydrogen in both, they are believed to be identical with gallotannic acid.

In an investigation of the darker tannin precipitated from aqueous solution by salt, the following percentages were obtained :

C,	55·18
H,	4·72
O,	40·10
	100·00

This product was considered to be a mixture of the tannin with its anhydride.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, April 5, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 5, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the balance in the treasury, and presented bills for lantern slides, printing, etc., which were approved and ordered paid. The Secretary announced the death of Mr. Thomas Hockley, active member, on March 12, 1892, and upon motion the chairman appointed a committee to draft suitable resolutions for the section.

Mr. C. H. Bedell read a paper on "Dynamo and Motor Calculation," with illustrations. Referred for publication.

Mr. Herbert S. Lloyd (visitor) described, with the aid of a working model, a new method of wiring incandescent lights, so that they could be controlled by switches from any number of points, on two or three-wire systems.

Prof. Houston read a letter from Prof. Elihu Thomson, in which the latter described some interesting experiments he had been making with alternating currents of high potential. It was also stated that Prof. Thomson would probably show these and other new experiments before the Section at a future meeting.

There was an informal discussion on the trolley system of electric street car propulsion, and on the conditions under which the passage of an electric current through the body would probably be fatal to life.

Prof. Rondinella proposed to amend Sec. 1 of Art. II of the By-Laws, by striking out the word "first" and inserting in its place the word "fourth," making the section read, "The Stated meetings of the Section shall be held on the fourth Tuesday of each month at 8 P. M., except during the months of July and August." (This amendment will come up for action at the next stated meeting.)

The meeting then adjourned. L. F. RONDINELLA, Secretary.

CORRESPONDENCE.

To the Committee on Publications, Franklin Institute, Philadelphia.

GENTLEMEN:—Will you kindly publish in your *Journal* a few remarks upon the article by C. B. Dudley, Ph.D., on pp. 81 and 93 of the *Journal*, current volume?

As a member of the firm of Torrey & Eaton, New York, I have given much attention to the analysis of bearing metals, having personally manufactured 1,000 tons of various alloys, and have carefully read the article by Dr. Dudley. Knowing his experience as an analyst and of his high standing as a member of the Mechanical Engineers, I was surprised to note that among the various analyses of bearing metals given, he has made several grave errors in the analysis of magnolia metal. This may work to the injury of a company which has done much to advance the interests of mechanics.

I am looking at this matter from an entirely scientific standpoint, and would not expect the *Journal* to take it up in any other way.

In the analysis of magnolia metal, Dr. Dudley has overstated one constituent part and has omitted tin (which it always contains) and other material. On the same page is given an analysis of antimonial lead, which may be correct, but not an ounce of this is ever used in magnolia metal, and the public will compare it with the magnolia analysis as given. This may work to the injury of the reputation of the makers of magnolia.

Respectfully yours, H. G. TORREY.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Brainard, F. R. *The Sexant.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Burke, M. D. *Brick for Street Pavements.* Cincinnati: Robert Clarke & Co. 1892. 8vo. Paper. Price, $1.

Church, I. P. *Notes and Examples in Mechanics.* New York: John Wiley & Sons. 1892. 8vo. Price, $2.

Duquesnay. *Résistance des Matériaux.* Paris: Gauthier-Villars. 1892. 16mo. Price, 3 francs.

Dwelshauvers-Dery. *Étude Experimentale Calorimetrique de la Machine à Vapeur.* Paris: Gauthier-Villars. 1892. 16mo. Price, 3 francs.

Gouilly, Al. *Transmission de la Force Motrice par Air Comprimé ou Raréfié.* Paris: Gauthier-Villars. 1892. 16mo. Price, 2 francs.

Merriman, M. *Text-Book on Retaining Walls and Masonry Dams.* New York: John Wiley & Sons. 1892. 8vo. Price, $2.

Ohm, G. S. *The Galvanic Circuit Investigated Mathematically.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Picon, R. V. *La Distribution de l'Électricité.* Paris: Gaulthier-Villars. 1892. 16mo. Price, 2 francs.

Plympton, G. W. *How to Become an Engineer.* New York: D. Van Nostrand Company. 1891. 24mo. Price, 50 cents.

Richard, Gustave. *Les Nouveaux Moteurs à Gaz et à Petrole.* Paris: Vve. Ch. Dunod. 1892. 4 vols. 8vo. Price, 75 francs.

Staley, C. and G. S. Pierson. *The Separate System of Sewerage.* New York: D. Van Nostrand Company. 1891.

Tillman, S. E. *Elementary Lessons in Heat.* New York: John Wiley & Sons. 1892. 8vo. Price, $1.50.

BOOK NOTICES.

A Manual of the Steam Engine. Part II. Design, Construction and Operation. By Robert H. Thurston, A. M., LL.D., Dr. Engineering. New York: John Wiley & Sons. 1891. Pp. xxiv, 934.

This second portion of this latest of Prof. Thurston's works is fully up to the standard of the first volume, and perhaps, from the full and able review of that portion in the *Journal*, little more need be said. The work is divided into chapters on design of the steam engine; design of valve gearing and steam distribution; regulation of the engine, governors, fly wheels and inertia effects; construction and erection; operation, care and management of engines; engine and boiler trials; specifications and contracts, and finance.

It is the last chapter that will be of most interest to engineers generally, as the author has here brought together a large amount of data not heretofore collated, and which will be interesting reading to every engineer. The blank forms used for determining costs, published by Mr. Towne in the *Transactions* of the American Society of Mechanical Engineers, are here reproduced together with the forms printed in the *Transactions* of the National Electric Light Associations.

Numerous instances of large savings from modifications of steam plants are given. Estimates are given as to the costs of large steam plants and of boilers, but it is not possible from the text to tell just what is included in the estimate. Tables follow giving the number of attendants required on vessels of different nationalities. Costs of engines and boilers under different conditions are given, which are valuable if one has the original papers at hand to determine the conditions under which the estimates are made. For instance, taking an engine from one of the tables we have a stationary non-compound engine of 56·8 I. H. P., cost $5,331 (of course meaning plant, but not saying so), using twenty-seven pounds water per I. H. P. and 3·27 pounds coal. This is rather an odd combination of figures, but may have been right when first printed in 1883.

This is followed by some costs of construction, taking the case of a passenger locomotive, and by the divisions of the labor costs among the different departments of a manufacturing establishment. The cost of repairs is then taken up and an example given.

The costs of operation are given for a few cases, noting the difficulty generally found in getting these costs exactly. Examples are given showing the cost of small engines using gas, steam and hot air. The relation of cost values and durability, and the arithmetical rules for computing interest are explained. The questions of the efficiency of the steam boiler from the designer's and from the owner's standpoint are stated.

The next point treated of is that of lubrication, and considerable data as to the amount of oil that has been used under different conditions have been collected. The author deduces an arithmetical solution of the treatment of this portion of the subject of costs. A table gives the cost of simple and of compound engines of from 250 to 700 horse-power and tables showing the daily and yearly running expenses of engines of various kinds and under various conditions.

A rather interesting thing is the plan of a steam plant in connection with which the author says: "The 'steam plant,' so-called, thus consists of the whole arrangement of engines, boilers, and all accessories, and its design frequently involves many important questions arising from the conditions of location, and of costs at the chosen locality. In the figure, these have been studied with a view to securing the best and most convenient location of parts, actually and relatively, etc. The plant referred to consists of two return tubular boilers and two engines driving four dynamos.

The subject of electrical energy is taken up and considerable space given to the conditions under which it is used and to the data relating thereto. The last article is devoted to the transmission of power and here again considerable valuable data have been collected.

While Prof. Thurston on the title page states that the work is intended for engineers and technical schools, it can be read with profit by any one interested in steam engines, as the mathematical parts are not at all essential to a fairly complete mastery of its contents, although there are some portions, as for instance those relating to inertia effects, which are rather beyond the comprehension of one not well versed in mathematics. H. W. S.

The Zodiacal Light. By M. A. Veeder, M. D. Extracted from *Proceedings of the Rochester Academy of Science.* Vol. i.

This is one of the many attempts made to explain the mysterious phenomenon known as the Zodiacal Light. The author attributes the phenomenon to light reflected from an extension of the solar corona, consisting of meteoric particles. The paper is attractively written and the explanations are at first sight plausible, but upon closer examination they fail to impart conviction to the reader. While the increased brightness observed during spring and autumn may be satisfactorily explained, it is not at all clear why the light should be brightest on the evenings of spring and the mornings of fall, since the spectator has practically the same standpoint on both mornings and evenings. Nor is there any reason why the phenomenon, as explained, should be seen most pronounced in the tropics. A difference of the point of observation of several thousand miles to the north or south of the equator, is so trifling that the observed diminution of the brightness of the light as the distance of thé equator is increased, cannot be accounted for. In order to still further confirm the existence of meteoric matter, the author suggests that these meteors take part in conveying those electric impulses from the sun to the earth, which, according to our experience, are transmitted during periods of solar eruptions. This assertion is also open to objections. These electric disturbances, being transmitted from the sun to the earth by induction and not by conduction, a transmitting medium is not required. H. B.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1891–92.

The attendance during these sessions has been greater than ever before, with the single exception of last year, again necessitating the division of the classes into two sets to attend on different evenings because of want of room in this very inadequate building. This department of the Institute is as poorly provided as the others with facilities and suitable appliances and surroundings for the proper prosecution of its useful and valuable work. It has led for years in the system and methods of teaching mechanical drawing, and is gradually reforming the science throughout the country, and yet has been compelled to do this at a minimum of expense and in unsuitable quarters.

The benefit of a systematic and progressive course has been well demonstrated by the work of the Senior Classes this year, which is of a higher average than ever before. This work is of too technical and scientific a nature to make a popular or attractive display, but the benefit to the student of receiving a thorough course of instruction, which will be important to his future, is far greater than if the time was spent in elaborately executing, coloring and shading a few show-pieces. The time of a night school is too limited to attempt results which would greatly impress the laity, and is much better spent in teaching principles and methods and in laying a solid foundation for the future.

The corps of instructors, comprising Messrs. Clement Remington, Lucien E. Picolet, George W. Irons, George S. Cullen, H. Allen Higgins and William H. Sheahan, possesses the great advantage that its members combine a thorough theoretical knowledge of their several branches with the practical application of them in actual work, and this circumstance has much to do with the great amount of benefit, which the intelligent pupils derive during their limited attendance at this night school.

The following pupils are entitled to Honorable Mention :

In the Junior Classes.

Arthur Bentley,
G. W. Hassellund,
James H. Leicht,
Henry J. Nelson,
A. F. Abronski,
William F. Troost,
Milton B. Stout,
T. F. Kelly.

In the Intermediate Classes.

Malcolm Lovett,
Howard R. Lamborn,
Austin Riegner,
James Marshall,
Samuel G. Barnard,
Bert. Bilhartz,
Eric Ostram,
N. Battle,
A. Martin Devoe,
Christian Hagenlocher.

In the Senior Classes.

Walter Hensel,
William Saile,
Bruce Ford,
Charles Rowe,
Abraham P. Weckerley,
William H. Simmons,
Joseph Royal,
William T. Westbrook, Jr.

In the Architectural Class.

George W. Raynor,
Charles P. Jarden,
Lewis C. Butler,
George H. Robinson,
Thomas Noble.

In the Free-Hand Class.

Robert F. Scheicher,
George T. Blaisse, Jr.,
Max L. Kohl,
Walter L. Allen,
Godfrey Semper.

The following pupils are awarded scholarships from the B. H. Bartol Fund, entitling them to tickets for the next term, beginning September 20, 1892 :

Walter Hensel,
William Saile,
George W. Raynor,
Malcolm Lovett,
Bert. Bilhartz,
Arthur Bentley,
A. F. Abronski,
William F. Troost.

The following pupils, having attended four terms and completed satisfactorily a full course, are awarded certificates :

Henry Aichele,
Edward C. Aitken,
Walter L. Allen,
Franklin W. Biedert,
George T. Blaisse, Jr.,
Julius Block,
Frederick Buehler,
Clifford I. Hewitt,
Joseph M. Hewlett,
George Lutner,
Alva S. Mackenzie,
Charles McLoughry,
John Rigling,
Charles Rowe,

Charles F. Cochrane,
George T. Coleman,
William S. Cooper,
Frank J. Crowne,
Lorenzo C. Dilks,
Jackson Dunlap, Jr.,
Henry B. Etter,
Herman Hammer,
Walter Hensel,
Andrew Sauer,
Godfrey Semper,
William H. Simmons,
George W. Todd,
Richard H. Trimble.
Paul G. Webb,
Allen Wilson,
Thomas M. Worn.

The next term will begin September 20, 1892, when endeavor will be made to maintain the progressive spirit of this department of the Institute.

WILLIAM H. THORNE, *Director.*

Franklin Institute.

[*Proceedings of the stated meeting, held April 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 20, 1892.

Mr. G. MORGAN ELDRIDGE, Chairman *pro tem.*

Present, forty-six members and five visitors.

Additions to membership since last report, eight.

The Secretary reported the death of Mr. Wm. A. Cheyney, auditor of the Institute, and moved the appointment of a committee to prepare a suitable memorial of the deceased. Carried.

Mr. E. H. Outerbridge, of New York, gave a description of a new article of manufacture, called "pantasote" leather, designed principally to serve as a substitute for leather, and especially for the more costly varieties of leather employed for upholstery, wall decorations, travelling bags, etc. The speaker illustrated his remarks by the exhibition of a series of lantern slides showing the process of manufacture, and of an interesting suite of samples of the finished products.

Mr. Thomas P. Conard presented a description, with lantern projections, of the Shay geared locomotive.

Mr. T. F. Cook, of Tacoma, Washington, followed with a description of a new method of transportation recently invented by him. The inventor employs an overhead system, the permanent way consisting of a single line of columns carrying an upper and lower girder. The invention consists further in an arrangement of horizontal pulleys which are carried on the lower girder, adapted to be driven by any suitable motive-power and by which motion is communicated to the cars. The latter are arranged to travel in opposite directions on the two sides of the elevated structure.

The Secretary read his monthly report.

Adjourned.

WM. H. WAHL, *Secretary.*

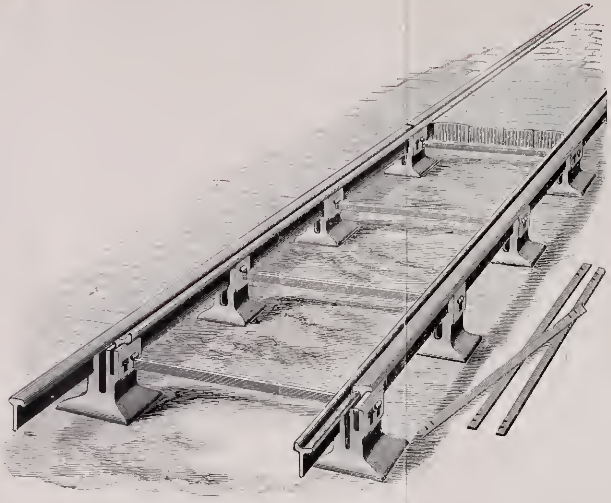


FIG. 1.

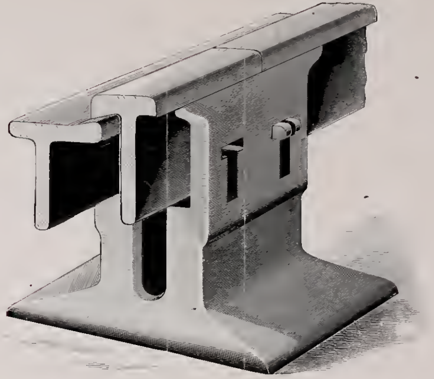


FIG. 2.

FIG. 1.—Gibbon duplex rail construction.
" 2.—Joint-chair and rail.
" 3.—Duplex rail.
" 4.—Cross-section at chair.
" 5.—Longitudinal section at joint.
" 6.—Tie-bar.
" 7.—Wedge-key.

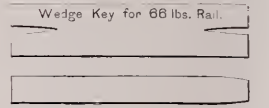


FIG. 7.

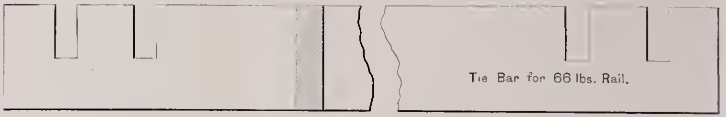


FIG. 6.

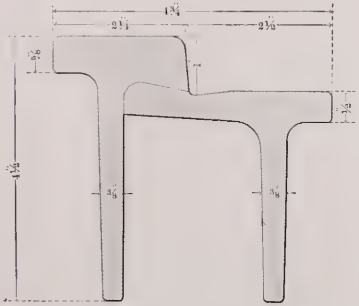


FIG. 3.

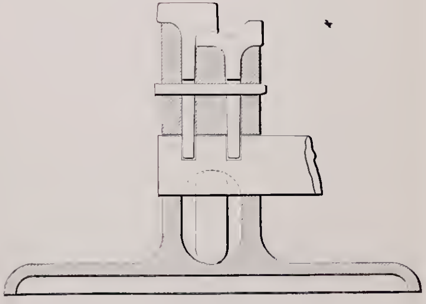


FIG. 4.

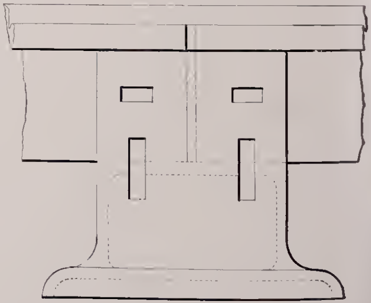


FIG. 5.

THE GIBBON DUPLEX STREET RAILWAY TRACK.

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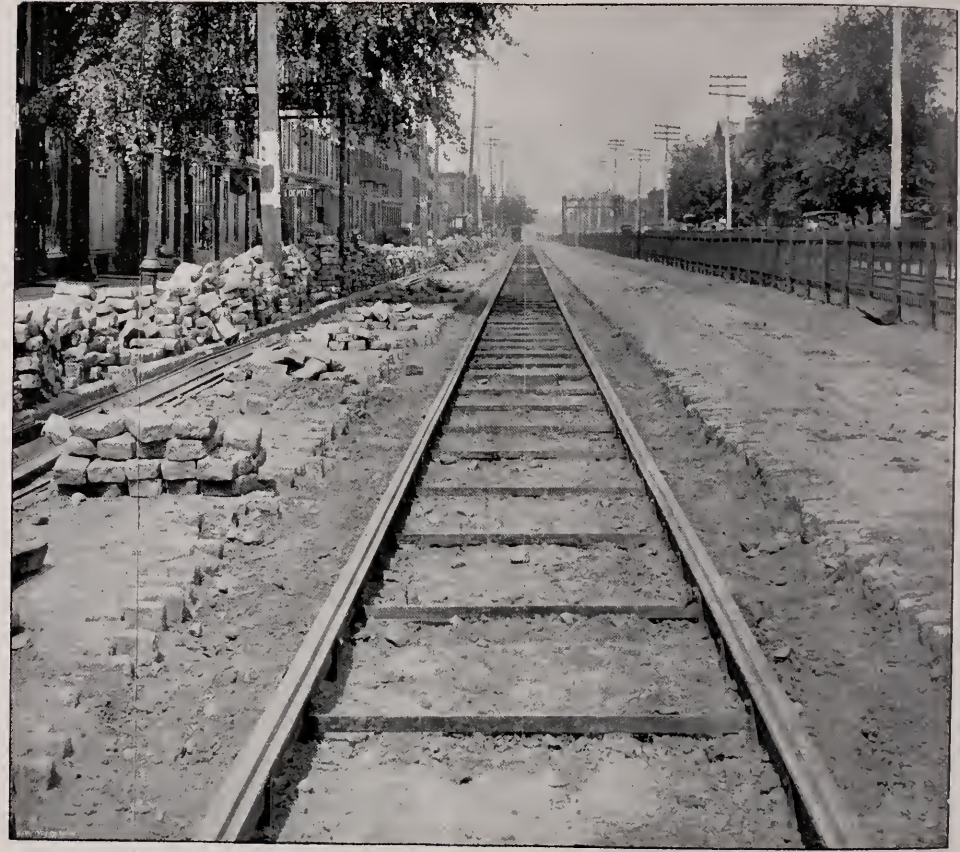

THE GIBBON DUPLEX STREET RAILWAY TRACK.—FINISHED TRACK.

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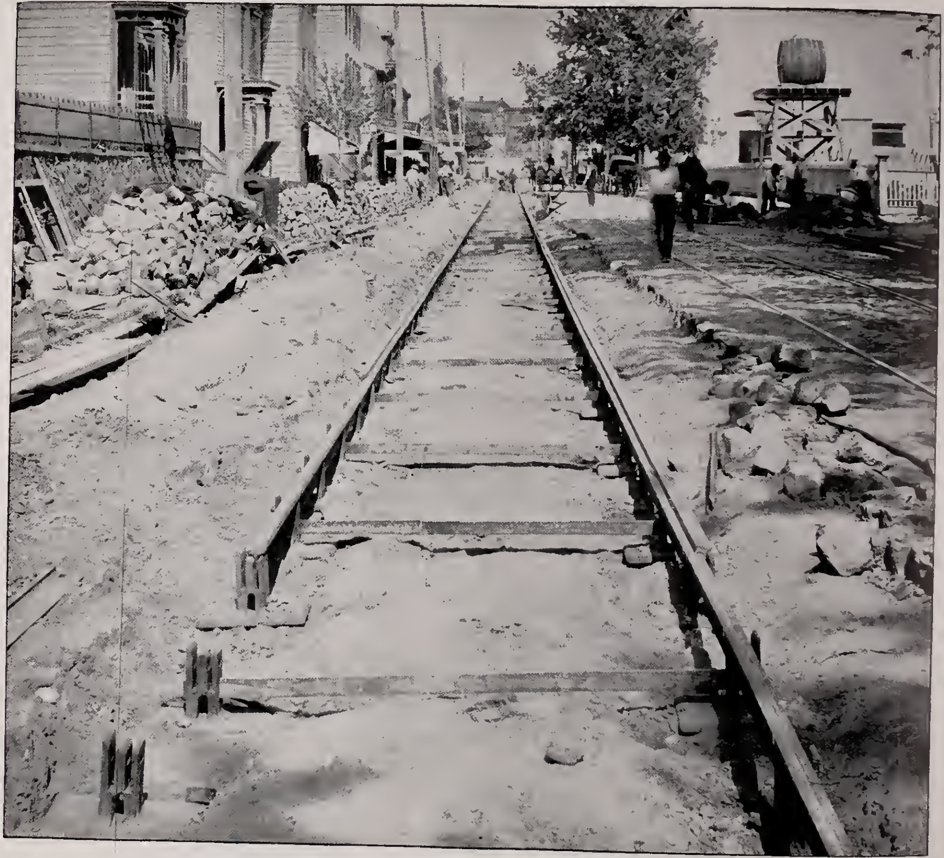

THE GIBBON DUPLEX STREET RAILWAY TRACK IN COURSE OF CONSTRUCTION.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIII. JUNE, 1892. NO. 6

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

GIBBON'S DUPLEX STREET RAILWAY TRACK.

[*Report of the Committee on Science and the Arts.*]

[No. 1,643.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 1, 1892.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination,

GIBBON'S DUPLEX STREET RAILWAY TRACK,

report, That the system embraces a form of construction for street railways that dispenses with wooden sills and cross ties, and substitutes therefor metal chairs and tie-bars as supports and braces, for a system of double rails of peculiar construction, in which the head and flange rails are separate, each having a wide depending web directly under the load bearing surface. These two sections, when united, form a complete rail, making a very stiff longitudinal stringer, laid to break joints, so that when the head sections meet they are supported by the solid portion of the flange section, and where the latter join they are covered partially by the solid head section, thus practically forming a jointless track of uniform strength and elasticity throughout its entire length.

A transverse section of this track exhibits two double rails—two cast-iron chairs, one tie-bar and two lock-wedges, as shown in the accompanying illustrations.

It will be noted that no spikes or threaded bolts are used, that the gauge of the track is absolutely uniform and permanent, being controlled by the notched tie-bars which receive the webs of the rails. Two patterns of cast-iron chairs are preferably used: the joint chair having slots and key-ways to receive two tie-bars and two key-wedges, and an intermediate chair having but a single tie-bar, slot and key-way.

The tie-bars are made from flat steel about two inches by one-half inch at each end to any desired gauge, to receive the webs of the rails.

The keys or wedges are split at one or both ends, and, being driven through the key-ways of the chairs directly over the tie-bars, and through openings in the webs of the rails, are securely held in place by slightly spreading the split ends, so that they will not come out accidentally, but are not difficult to remove when necessary.

The claims of superiority advanced for this system are fully discussed and illustrated in the letters patent Nos. 429,127 and 429,128, dated June 2, 1890, and other papers forming an appendix for reference; but briefly stated, they appear under the following heads:

(1) "Durability and permanence, inherent to an all-metal system." This claim passes without question.

(2) "Smoothness and stability of the track, which is absolutely free from weak points."

When a track is constructed so that the ends of the rails cannot yield to the passing load, the worst of all track-destroying causes is removed, and such a road must retain its smoothness and stability until the rails are entirely worn out throughout their length.

(3) "Increased vertical and lateral strength without increase of metal."

The double rail with the two vertical webs combined and secured by the metal chairs, tie-bars and wedges, is naturally very stiff, in all directions; this is mainly due to the better disposition of the metal with relation to the direction of the load and strain.

(4) "Freedom from torsional strain, the bearing surfaces being directly supported by the vertical webs."

The prevailing form of a street track in America provides for two kinds of service, a head to carry the car and a flange upon which other vehicles may run.

In single girder rails, the one vertical web is not placed directly under either of these load-bearing portions, but between them, so that there is no direct support for either car or wagon, which brings upon such a track a serious and injurious twisting strain. In the Gibbon rail, which has the two vertical webs directly under each of the load-bearing surfaces, similar twisting is impossible.

(5) "Increased wearing capacity of head rail."

On tracks constructed so that wagons cannot travel upon them, or where the wagon travel is much lighter than the car service, the head of the rail will wear out most rapidly; when this occurs upon a single girder rail the entire rail must be discarded as scrap, while with the Gibbon system, only the head rail need be renewed, and the discarded part is but half the weight of the single girder.

(6) "In renewal, the discarding of the worn portion only is necessary."

The advantage of retaining either half of the rail in service until it is worn out, adds greatly to the life and economy of such a track.

(7) "Perfect alignment and accurate maintenance of gauge with requisite freedom for expansion and contraction."

The union of the rails with the tie-bars and keys at the chairs is such that, while the rails are firmly seated in the chairs and securely held down by the keys, the eyes in the rail-webs being longer than the width of the keys, ample play for expansion is provided.

(8 "Simplicity of construction which expedites the track laying and reduces the disturbances of the public streets."

Every piece of the Gibbon track is of the simplest form and inexpensive to make, and in the construction of a mile of track but 7,850 pieces are required, while some of the permanent single girder tracks are made up of over 26,000 pieces and the common tram rail uses 17,406 pieces per mile. In excavating for these tracks the quantity of earth to be removed bears about the same ratio, viz: for the Gibbon track 300 cubic yards and for the others 1,064 cubic yards, and 932 cubic yards, respectively. These advantages bring the cost of the superior all-metal Gibbon track within the cost of the ordinary tram track.

(9) "Maintenance of absolute contact of metal, which obviates the necessity of 'bonding joints' for electrical traction."

This claim is doubtless well founded; the method of connecting the rails at their ends is such that for electrical service the track is found to be practically and permanently as one continuous rail.

(10) "A reasonable first cost, and great saving in maintenance."

For reasons above stated, this claim must be conceded.

From a careful examination of this system and an inspection of tracks in practical use, it is evident that much that has long been desired in the direction of a better and more lasting construction, permanent smoothness and strength equal to the heavy traffic that they are subject to, has been carefully and ably worked out upon a thoroughly practical and economical line, in every detail.

The special requirements of electrical traction and cable service appear to be fully met, so that we have an excellent substitute for every objectionable form of track now commonly used.

An invention that will contribute so much to the daily comfort of every one who must use the street cars, and that at the same time materially reduces the annoyance of the ever-recurring repairs to the present prevailing systems, commends itself to the highest appreciation of all.

We therefore respectfully recommend the grant to the inventor of the award of the John Scott Legacy Premium and Medal.

H. R. HEYL, *Chairman*; J. M. EMANUEL,
SPENCER FULLERTON, CHAS. E. RONALDSON,
ARTHUR BEARDSLEY, G. MORGAN ELDRIDGE,
L. L. CHENEY.

Adopted, May 4, 1892.

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

THE DEVELOPMENT OF AMERICAN ARMOR-PLATE.

BY F. LYNWOOD GARRISON.

[*Continued from p. 356.*]

Alloyed Steel Armor.—As far as the author can determine the use of what has been termed "alloyed steels" for the manufacture of armor-plate was begun on an entirely experimental basis, about the year 1881.

During this year, some *chrome* steel plates made at Creusot and at Unieux were tested at the Gavre proving grounds in France. These plates were composed of square slabs, fastened to a solid backing of iron.

The experiments were not so successful as anticipated, the first projectile shattering the plate almost to pieces. This result was attributed to the fact of the iron backing not being sufficiently solid, and to the difficulty of getting the iron and steel to make an efficient compound.*

Since 1881, some few experimental plates of chrome, manganese or copper steels have been made in France; as far as the author knows the results were not made public, and he infers they could not have been satisfactory.

The one alloyed steel, which has been used to any extent within the last two or three years, is nickel steel; it was first used in a practical manner as armor-plate in France.

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* *Journal of the Iron and Steel Inst.*, No. 1, 1881, p. 329.

Henri Schneider, of Creusot, in his patent specifications for the manufacture of alloys of steel and nickel, and steel and copper, mentions that such alloys are especially adapted or suitable for use in the construction of armor-plates.* For several years it has been a well-known fact amongst metallurgists that alloys of certain properties of nickel and steel are made more thoroughly homogeneous, stronger and harder by the presence of the nickel. Nickel steel withstands punching without cracking to a marked degree; it forges, rolls and tempers well, and can be cast into shapes without difficulty.

In 1891, Capt. Tresidder obtained a British patent† for the use of a nickel steel back instead of wrought iron or steel, in the manufacture of the Ellis (Brown & Co.) compound plates.

He states in the specification that about two per cent. of nickel is added to the Siemens–Martin steel used for the purpose, also that such nickel-steel is equally applicable to compound plates made in any other manner. The use of these nickel-steel backs is possibly as important if not the most important factor in the success of the so-called Tresidder process which will be considered later on.

One of the first nickel-steel plates made by Schneider & Co., at Creusot, was tested by the Russian Government at Ochta, November 11, 1890.

The now famous nickel-steel plate, tested at Annapolis in September, 1890, was made at Creusot about a year after the Ochta plate, and, as a consequence, might be expected to be the superior owing to the improvements which naturally would be made in the process of manufacture during that interval.

The Ochta plate did not develop as good qualities as had been expected, but it proved much superior to the Brown compound plate, and the Vicker's all-steel plate tested at that time; only two of the projectiles getting their points beyond its back.

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* U. S. Patents 415,655 and 415,654, November 19, 1889.

† No. 2,552, of 1891.

The rebounding of the projectiles from the nickel-steel plate showed it to be much more elastic than the all-steel, the latter acting more like good wrought iron when attacked by projectiles of the best quality. One especially noticeable feature in the nickel-steel plate should be kept in mind—that of the little effect of its many cracks on the penetration of succeeding projectiles.[*]

M. Barba states[†] that he cannot see the necessity of seeking so earnestly the suppression of cracks since they do not exercise any influence upon perforation. By giving the steel a laminated structure, assisted by the introduction of nickel, it is possible to keep back the apparition of cracks, but M. Barba did not think in any metal they could be done away with altogether.

It is difficult to determine just how the nickel acts in a beneficial manner when added to steel; that nickel has a very strong affinity for iron, we have demonstrated in its almost invariable presence in meteoric iron.

Vickers denies the supposition that nickel could give a laminated structure to cast steel. He states that when a projectile strikes a plate the metal must be distorted, and if that leads to cracking, it is likely to be called lamination. He had noticed cracks beneath and parallel with the surface were often thought to be due to lamination.[‡]

Barba states that the presence of cracks depend very much upon the nearness of the point of impact of the shot to the edge and that they might be prevented by the proper metallurgical treatment.[§]

Mr. W. H. White (Director of Naval Construction of the British Admiralty) states, that he has seen cracks take place

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[*] *The Year's Naval Progress*, p. 303. Washington, 1891.

[†] *Proceedings of the Institution of Naval Architects*, 1891. *Engineering*, vol. li, 1891, p. 393.

[‡] *Ibid.* (*Engineering*), p. 393.

[§] *Ibid.*, p. 396.

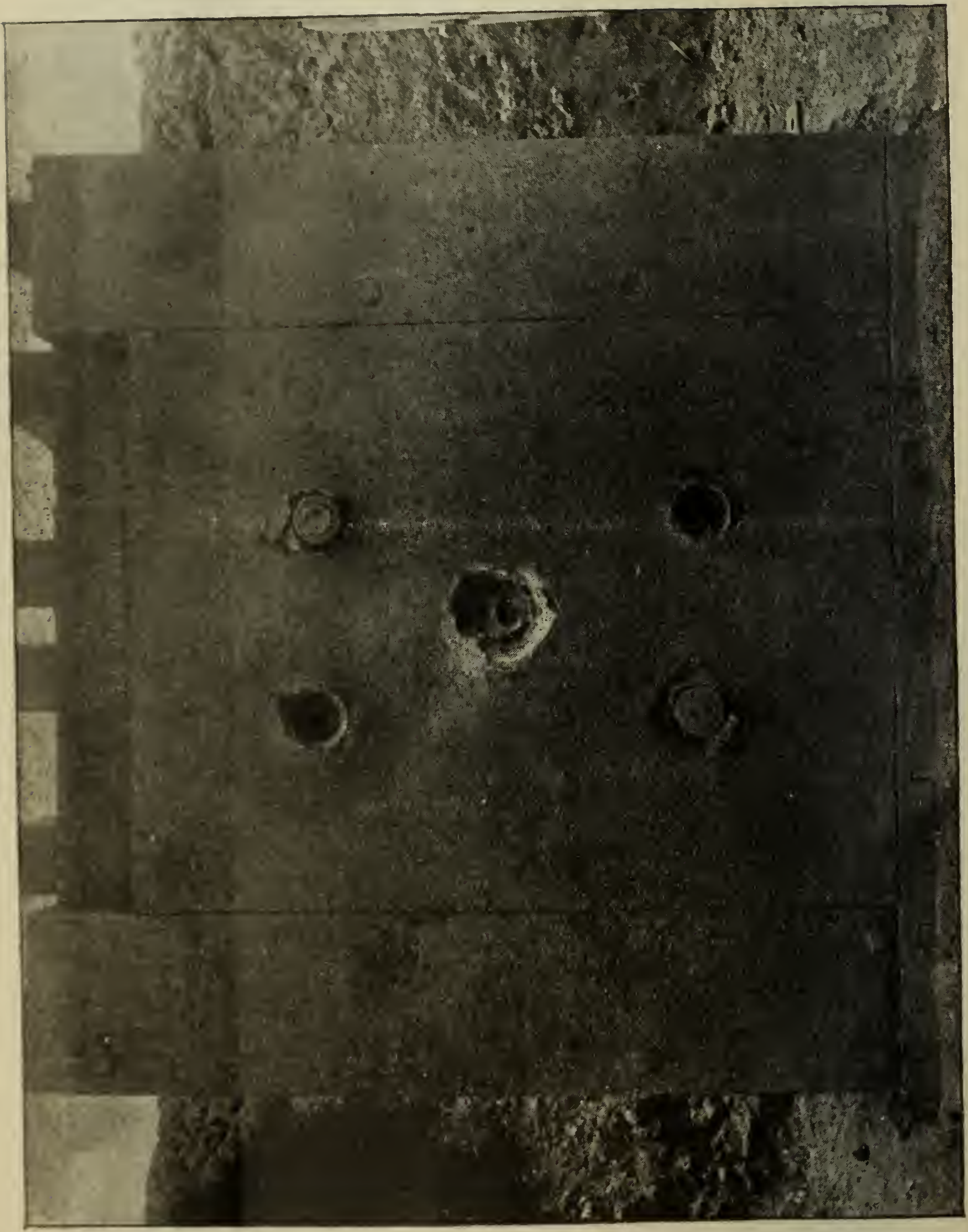

FIG. 6.—Creusot nickel-steel plate.

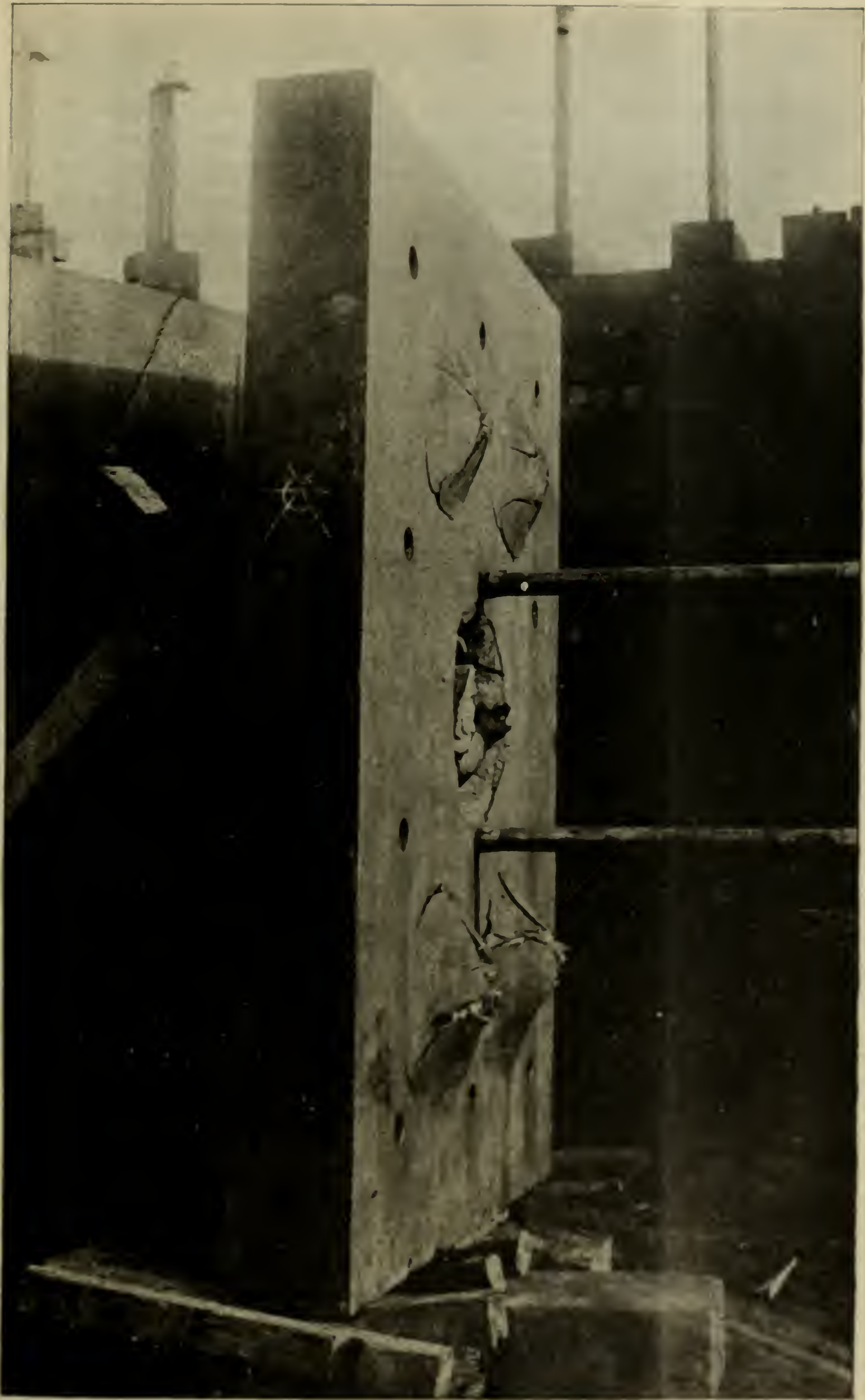

FIG. 7.—Creusot nickel-steel plate (back)

at some distance from the shot. What the cause might be it is difficult to say, and how far the effect might be serious for cracks of given dimensions, it was also difficult to decide.*

The results of the Annapolis trials of 1890 are too well known to need further comment.† The resistance obtained with the nickel-steel plate far exceeded the expectations. At the fifth shot, with a striking energy of 4,988 foot-tons, an eight-inch armor-piercing projectile broke in many pieces after having forced its point but ten and one-half inches beyond the back and without developing a sign of a crack. (See *Plate I.*) This armor-plate showed as much homogeneity as the steel one, but was tougher and more tenacious. (*Figs.* *6* and *7.*) Never before, in the history of modern armor, had a plate given results to compare with these; withstanding a total energy of 16,940 foot-tons—1,835 foot-tons per ton of plate—without developing a single crack and without being perforated.‡ The dimensions of both these nickel-steel plates were much the same, the Ochta being 8 x 8 feet square and about ten inches thick, and the Annapolis 6 x 8 feet by 10½ inches thick.

They differed somewhat in composition, containing unequal proportions of nickel. Up to the time of the Annapolis trials no nickel-steel plates of any great size appear to have been made in England, although about that time and since, considerable quantities of four-inch nickel-steel deck plates have been made and tested on board the *Nettle*, with very satisfactory results.§ It has been officially stated such plates yielded results seventy-five per cent. above similar plates ever tested in England.‖ Similar results were obtained by the French, Danish and Chilian Admiralty officials.

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* *Engineering*, p. 396.

† See *The Year's Naval Progress*, July, 1891. *Proceedings of the U. S. Naval Inst.*, vol. xxi, No. 5. *Journ. of the Franklin Inst.* Report of the Secretary of Navy.

‡ *Ibid.*, p. 326.

§ *Journal of the Iron and Steel Inst.*, No. 11, 1891, p. 51.

‖ *Trans. of the Am. Inst. of Mining Engineers*, vol. xix, p. 832.

At the present time the development of nickel-steel in England appears to be in its application to compound plates by the system of Captain Tresidder already mentioned.

The author assumes the nickel-steel deck plate made in this country to have given equally good results. Some of it made by Carnegie, Phipps & Co., showed by analysis the following composition:*

	I.	*II.*
Carbon,	= 0·90	0·88
Phosphorus,	= 0·018	0·021
Manganese,	= 1·05	1·101
Silicon,	= 0·059	0.078
Nickel,	= 2·39	2·50
Sulphur,	= 0·014	0·016
Specific gravity,	= 7·801	7·853

This metal is presumably up to the United States Navy standard of 85,000 pounds tensile strength and twenty per cent. elongation.

Two nickel-steel plates of 10·43 and 9·84 inches in thickness, respectively, were tested at Gavre, in July, 1891, yielding results very similar to those obtained with the Creusot nickel-steel plate at the Annapolis trials of 1890.†

Triple Alloys.—What might be termed triple alloys of steel are beginning to attract some attention, and it would seem probable in the near future they may be used to some extent in the manufacture of armor-plate. Already the *Compagnie des Hauts-Fourneaux, Forges et Aciéries de la Marine et des Chemins de Fer* in France have made some experimental armor-plate of a 0·4 per cent. carbon steel with one per cent. chromium and two per cent. nickel, the steel being first melted in an open-hearth furnace in the ordinary way. When the silicon and manganese normally present in the steel have attained their proper proportions, the nickel and chromium are added successively in the form of ferro-nickel and ferro-chrome, or in the shape of a double ferro-chrome and nickel.‡

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* The author is indebted for this analysis to Mr. James S. de Benneville, of Philadelphia.

† *Le Yacht*, October 24, 1891.

‡ *Engineering and Mining Journal*, January 23, 1892, p. 131.

The design of the alloy is obvious, as it is evident the nickel is intended to give the toughness and the chromium the hardness.

If by this means conditions in armor-plate could be obtained similar to those in the Harvey treated nickel-steel plates at the recent Indian Head trials, we would truly have an ideal plate—ideal at least until the power of the gun has outgrown its present proportions. The author ventures to hope this ideal will at least in some measure be realized, for he believes the development of armor-plate in this direction to be the true one.

The recent armor-plate trials held at Indian Head, Md., the subject of which should properly constitute this paper, were held in three series, the first October 31st, the second November 14, 1891, and the third January 13, 1892.

Commander Wm. M. Folger, Chief of the Bureau of Ordnance, Navy Department, having requested that the Franklin Institute be represented at these trials, the author had the honor of being selected as its delegate.

He was present at the first two series, but owing to the date of the third having been decided upon somewhat unexpectedly, he was unable to attend. The results of the third series were, however, of comparatively little interest, being more or less of a repetition of those of the first and second series.

It was the intention of the Navy Department to test three plates of different composition at each of the three series, making a total of nine plates, all substantially of the same dimensions and weight.

This plan, however, was only carried out in the first and second series, as but two plates of somewhat irregular dimensions were tested at the third series.

For this reason the author will confine his remarks about these tests chiefly to the first two series, and for the sake of greater accuracy draw more of the details from the official report than from his own notes.*

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* The photographs which are used to illustrate these trials are those taken by the Board; the author is indebted to Commander Folger for the loan of the same, and also to the United States Naval Institute, and to the publishers of the *Iron Age* for a number of the others.

The size of each plate was 8 x 6 feet x 10·5 inches and it was fastened to the backing by twelve bolts 2·36 inches in diameter, giving a total bolt cross-section of 52·29 square inches. Further details are—*

Character of Plate.	Maker.	Weight.	Total Bolt Cross-section per Ton of Plate.
		pounds.	*sq. inches.*
High-carbon nickel-steel, ...	Bethlehem Iron Company, .	20,494	5·71
Low-carbon nickel-steel, ...	Carnegie, Phipps & Co.,	20,844	5·62
Low-carbon steel, Harvey, ...	Bethlehem Iron Company, .	20,5[illegible]	5·71
High-carbon nickel-steel, ...	Carnegie, Phipps & Co., .	20,5[illegible]	[illegible]
Low-carbon nickel-steel, Harvey, . . .	Carnegie, Phipps & Co., .	20,[illegible]	5·7[illegible]
High-carbon nickel-steel, Harvey, . . .	Bethlehem Iron Company, .	20,682	5·[illegible]

The targets were set up so that the faces of the plate were on the chords of a circle whose centre was the gun's pivot and whose radius was 73 feet 5 inches. The muzzle of the six-inch B. L. R. was consequently 57·5 feet and the eight-inch B. L. R. 55·5 feet from the face of the plate when the gun was pointed at its centre, the axis of the gun being then perpendicular to the plane of the plate.

The backing was constructed in accordance with the drawings furnished by the Bureau of Ordnance, except that, on account of the length of the armor bolts, on the first day wooden and on the second iron washers were used under the cup washers of these bolts. During the first day's firing some of the wooden washers were split and somewhat compressed and the armor-plate bolt nuts were in some cases tightened between the shots.

The surfaces of the plates were as they came from the makers and were free from paint.

The gun was mounted on a solid platform and protected overhead by a shed of heavy timbers, and in front by a bank of earth, with sand-bags around the chase.

The guns were pointed by means of cross-hair sights in the bore, and were fired by friction primers with a long lanyard leading to the bomb-proof near the gun, 18 feet distant.

In this report "front," when applied to the plate or to fragments thrown therefrom, will mean the direction from the plate towards the gun. The swellings of the plate caused by the projectile will be called the "front bulge" and the "back bulge." "Right" and "left" will be taken as the right or left-hand of a person facing the front of the plate. "Perforation" will indicate that the hole through the plate is in its entire length, as great or greater than the maximum diameter of the projectile.

BALLISTIC DETAILS.

Six-inch B. L. R.

Gun.—Six-inch B. L. R. of forty calibre: Mark III. No. 1[illegible].

Charge.—42·4 pounds Du Pont's brown prismatic powder.

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* The details in small type are from the official report of the Board, those in large type from the author's notes. F. L. G.

Projectile.—Six-inch armor-piercing shell, manufactured by Jacob Holtzer & Co., Unieux, France, brought up to the standard weight of 100 pounds by filling with sand and small fragments of iron.

Striking velocity, determined by previous firings, foot-seconds,	2,075
Striking energy, foot-tons,	2,989
Striking energy per ton of plate, about (foot-tons),	325
Elevation for upper corners,	+ 1° 44′
Elevation of lower corners,	— 1° 24′

Carriage.—Central pivot, Mark IV. No. 93.

Eight-inch B. L. R.

Gun.—Eight-inch B. L. R. of thirty-five calibres, Mark III. No. 18.

Charge.—74·5 pounds Du Pont's brown prismatic powder.

Projectile.—Eight-inch Firminy armor-piercing shell, manufactured by T. Firth & Sons, Sheffield, England, brought up to the standard weight of 210 pounds by filling with sand and small fragments of iron.

Striking velocity, determined by previous firings, foot-seconds,	1,850
Striking energy, foot-tons,	4,989
Striking energy per ton of plate, about (foot-tons),	543

When the Carpenter projectile was used:

Charge.—72·5 pounds of Du Pont's brown prismatic powder.

Projectile.—Eight-inch armor-piercing shell, manufactured by the Carpenter Steel Company, Reading, Pa., brought up to the standard weight of 250 pounds by filling with sand and small fragments of iron.

Striking velocity, foot-seconds,	1,700
Striking energy, foot-tons,	5,008
Striking energy, per ton of plate, about (foot-tons),	545

Carriage.—Central pivot, Mark IV. No. 15.

The total striking energy of the five projectiles was 16,940 foot-tons, equal to about 1,845 foot-tons per ton of plate.

FIRST DAY, OCTOBER 31, 1891.

Weather clear; thermometer at 9 A. M., 52° F.; at 2 P. M., 70° F.

Round 1.

First shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 8:48:45 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered the plate and rebounded to the front 31 feet 10 inches, and ricocheted 19 feet 2 inches beyond. The projectile was unbroken, and was shortened 0·06; expanded at bourrelet 0·01, at body 0·03, at base 0·00.

The penetration of the point was 13·25 inches.

A bulge was formed on the face of the plate 16·5 inches in diameter, with a regular and curling fringe of metal about the hole 1·75 inches high, and radial hair cracks in the bulge 4·5 inches and 2·5 inches long.

The bulge on the back of the plate was 16·5 inches in diameter, about the hole 1·75 inches wide; opposite the point of the projectile, from which a star of cracks opened out. A piece of metal about one-third the bulge was scaled off the back of the plate.

The indent in the backing corresponded in shape to the back bulge and was 11 inches in diameter and 1·75 inches deep.

The head of one of the side plate bolts was broken.

(See *Figs. 8, 9* and *14.*)

A through crack was subsequently developed at this point. The penetration was somewhat less than the first shot at the Creusot nickel-steel plate of the Annapolis trials in 1890.

Round 2.

First shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel plate. Time, 8:56 A. M.

Gun—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered and remained in the plate apparently intact, with its base 9·75 inches inside the face of the plate.

The estimated penetration of the point was 26·53 inches.

A bulge was formed on the face of the plate 18·5 inches in diameter, with a regular and curling fringe of metal about the hole 1·75 inches high.

No cracks.

When the plate was removed from the backing the projectile remained in the latter, with its base 1·5 inches from the normal surface thereof.

The bulge on the back of the plate was 16·5 inches in diameter, and 4·87 inches high about the hole through which the projectile passed.

The indent in the backing corresponded in shape to the bulge, and was 11 inches in diameter and 4 inches deep. Two small pieces of the plate adhered to the backing. One of the side plate bolts was loosened.

(See *Figs. 10, 11* and *14.*)

A thorough crack was subsequently developed at this point.

Round 3.

First shot at Bethlehem Iron Company's low-carbon steel Harvey plate. Time, 9:9:50 A. M.

Gun—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered and broke up; the head split into twelve pieces with a very jagged fracture and remained in the plate, and the base was broken into small pieces, one of the larger of which being found 100 yards to the front. The front end of the charge chamber was 2·75 inches inside the face of the plate.

The estimated penetration of the point was 10·07 inches.

A bulge was formed on the face of the plate, 19 inches in diameter, with a maximum height about the hole of 0·75 inch. There was no curling fringe, but the metal about the hole chipped off.

The bulge on the back of the plate was 16 inches in diameter and 2 inches high, with a star of cracks opening from the point of the projectile.

The backing showed a slight depression, corresponding in shape to the bulge, 12 inches in diameter and 1·5 inches deep.

Two of the side plate bolts were loosened.

(See *Figs 12, 13* and *14.*)

Round 4.

Second shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 9:20:28 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 22·5 inches from the top and 24 inches from the right side of the plate.

The projectile entered and broke into several pieces, the head with a jagged fracture and split into three equal pieces remaining in the plate. The front end of the chamber was 2·75 inches inside the face of the plate.

The estimated penetration of the point was 10·07 inches.

A bulge was formed on the face of the plate 18·5 inches in diameter with a regular and curling fringe about the hole 1·75 inches high. Three short surface radial cracks were developed in the bulge, 2 inches, 2·5 inches and 2·75 inches long.

The bulge on the back of the plate was 17 inches in diameter, and 2·12 inches high; about the hole one inch wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 11 inches in diameter and 1·37 inches deep.

One of the side plate bolts was loosened. The top of the plate was separated from the backing 0·5 inch.

(See *Figs. 8, 9* and *14.*)

Round 5.

Second shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel plate. Time, 9:31:45 A. M.

Gun.—Six-inch B. L. R

The point of impact was 24 inches from the top and 24 inches from the right side of the plate.

The projectile entered and remained in the plate, broken into two pieces, with its base 9 inches beyond the surface of the plate.

The estimated penetration of the point was 26·32 inches.

A bulge was formed on the face of the plate 18·75 inches in diameter, with a regular and curling fringe about the hole 1·75 inches high.

No cracks.

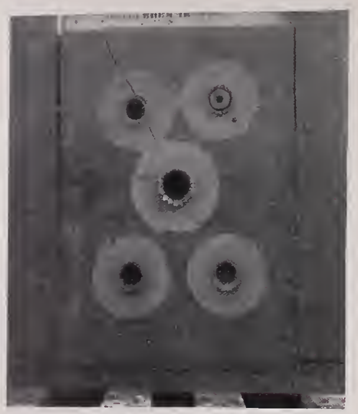

FIG. 8.—High-carbon nickel steel, Bethlehem.

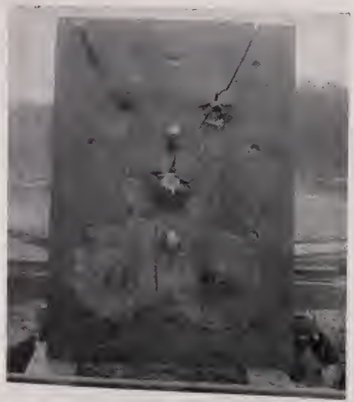

FIG. 9.—High-carbon nickel steel, Bethlehem (back).

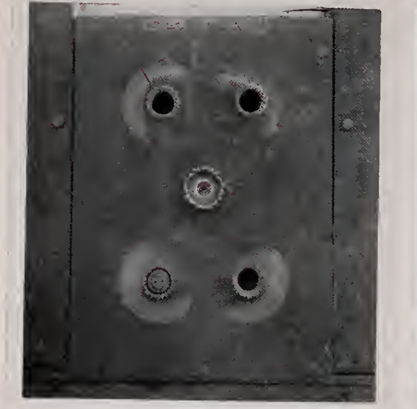

FIG. 10.—Low-carbon nickel steel, Carnegie (face)

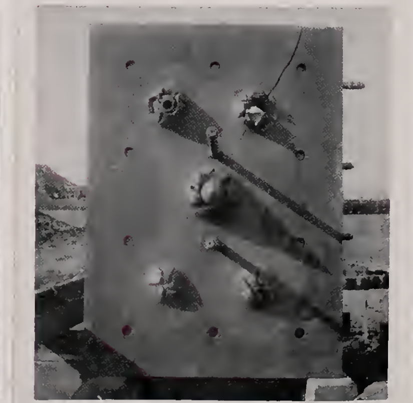

FIG. 11.—Low-carbon nickel steel, Carnegie (back).

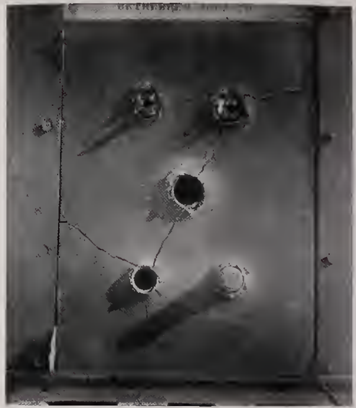

FIG. 12.—Harvey low-carbon steel, Bethlehem (face).

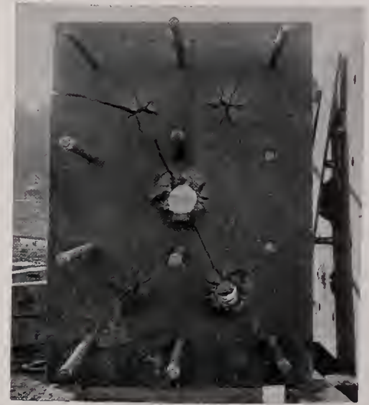

FIG. 13.—Harvey low-carbon steel, Bethlehem (back).

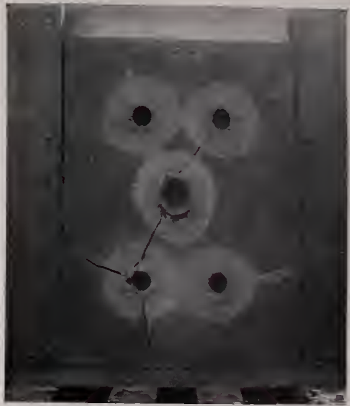

Fig. 15.—High-carbon nickel steel, Carnegie.

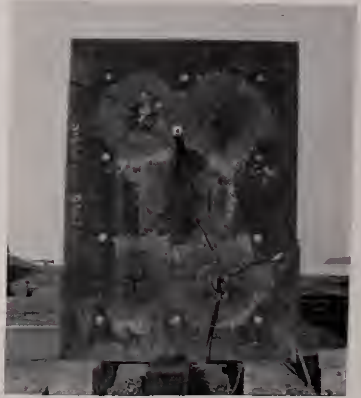

FIG. 16.—High-carbon nickel steel, Carnegie.

FIG

FIG. 1

THE INDIAN HEAD ARMOR TESTS.—TEN AND ONE-HALF INCH NICKEL STEEL PLATES BY CARNEGIE, PHIPPS & CO. AND BETHLEHE

PART THEREOF TREATED BY THE HARVEY PROCESS. FOUR ROUNDS SIX-INCH B. L. R., ONE ROUND EIGHT-INCH B. L. R.

(*Garrison.*)

Bethlehem (face).

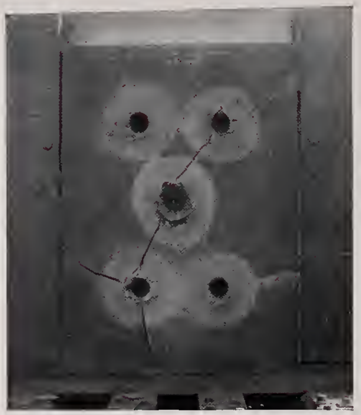

Fig. 15.—High-carbon nickel steel, Carnegie.

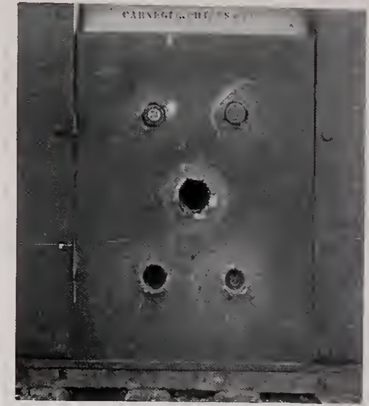

Fig. 17.—Harvey low-carbon nickel steel, Carnegie (face).

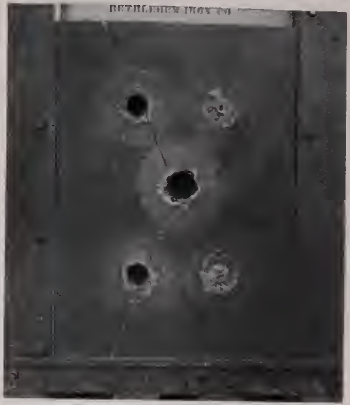

Fig. 19.—Harvey high-carbon nickel steel, Bethlehem.

ethlehem (back).

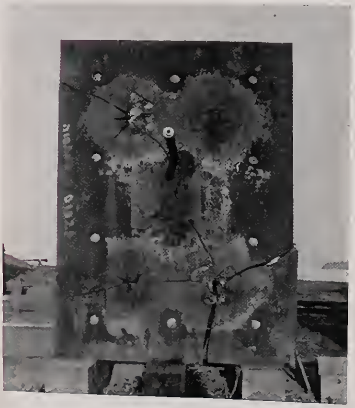

Fig. 16.—High-carbon nickel steel, Carnegie.

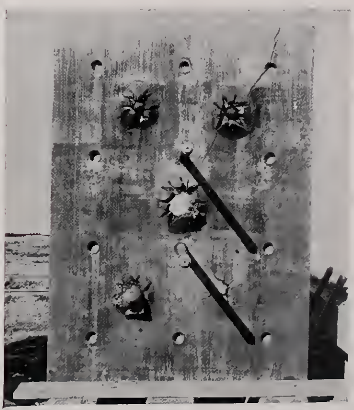

Fig. 18.—Harvey low-carbon nickel steel, Carnegie (back).

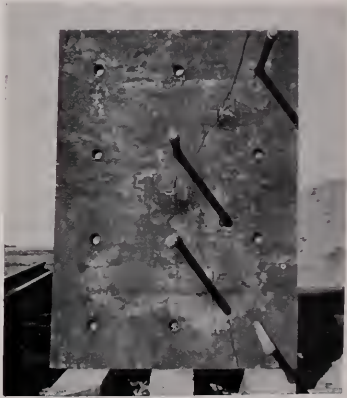

Fig. 20.—Harvey high-carbon nickel steel, Bethlehem.

NCH NICKEL STEEL PLATES BY CARNEGIE, PHIPPS & CO. AND BETHLEHEM IRON COMPANY.

EY PROCESS. FOUR ROUNDS SIX-INCH B. L. R., ONE ROUND EIGHT-INCH B. L. R.

When the plate was removed from the backing the projectile was found broken at the rotation band, the head sticking in the backing and the base in the plate.

The bulge in the back of the plate was 17 inches in diameter and 4·5 inches high.

The indent in the backing corresponded in shape to the back bulge, was 11 inches in diameter and 4 inches deep. Two small fragments of the plate adhered to the backing.

The upper part of the plate was sprung away from the backing 0·5 inch. (See *Figs 10*, *11* and *14*)

Round 6.

Second shot at Bethlehem Iron Company's low-carbon steel Harvey plate. Time, 9:41:20 A. M.

Gun —Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the right side of the plate.

The projectile entered and broke up, the head with a very jagged fracture remained in the plate. The body of the shell broke into many fragments. The front end of the charge chamber was 2·37 inches inside the face of the plate.

The estimated penetration of the point was 9·7 inches.

A bulge was formed on the face of the plate 18 inches in diameter with a maximum height about the hole of one inch. There was no curling fringe, but the metal about the hole was chipped off. A crack probed 5 inches deep, but was probably through, and extended from the hole to the right side of the plate 18·37 inches from the top.

The bulge on the back of the plate was 18 inches in diameter and 1·62 inches high with a star of cracks opening out from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and one inch deep.

Several of the side plate bolts were started and loosened and the upper left corner of the plate was sprung away from the backing 0·25 inch.

(See *Figs. 12*, *13* and *14*.)

A crack formed from point of impact to right hand edge which subsequently developed into a large through crack.

Round 7

Third shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 9:53:20 A. M.

Gun.—Six-inch B. L. R.

The point of the impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered and rebounded unbroken to the front 15 feet, ricocheted 10 feet 6 inches farther, striking an oak timber and rebounded 7 feet. It was shortened 0·06 inch, expanded at bourrelet 0·02 inch, at body 0·035 inch, at base 0·0 inch.

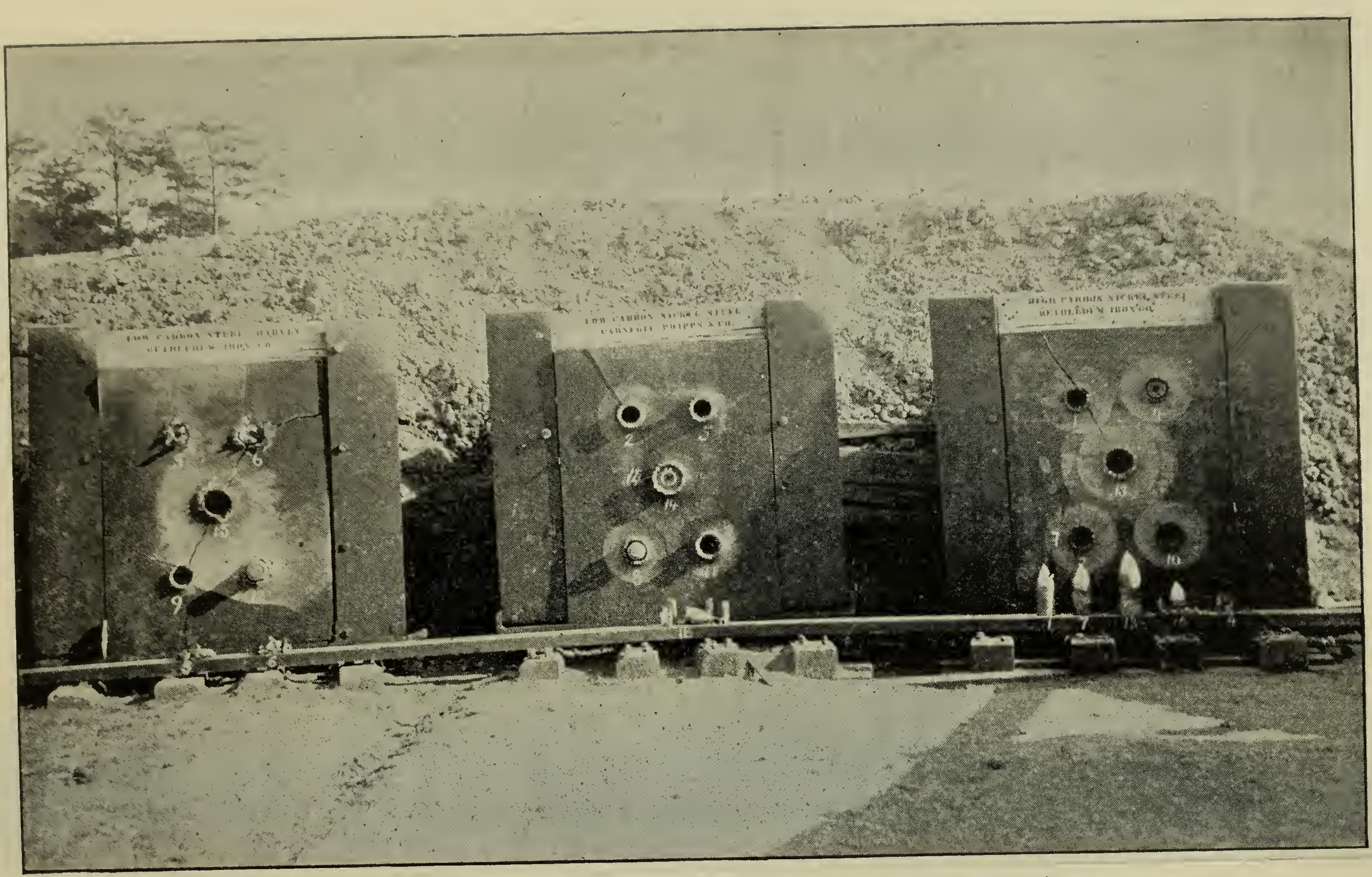

FIG. 14.—Targets after Round 15. (First day, October 31, 1891.)

The projectile was shortened 0·11 inch and expanded at the bourrelet 0·03 inch, at the body 0·08 inch, and at the base 0·02 inch.

The penetration of the point was 11·87 inches.

A bulge was formed on the face of the plate 18 inches in diameter with a curling fringe about the hole, partly chipped off, 1·87 inches high, and several radial hair cracks in the bulge not over 3 inches long.

One through crack extended from this through No. 3 hole to the side of the plate, 35·5 inches from the left lower corner, and the one mentioned in round 7 was slightly opened.

The bulge on the back of the plate was 20 inches in diameter and 2·87 inches high around the hole, 2·65 inches wide, opening out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 11 inches in diameter and 2 inches deep, with a small fragment of the plate sticking therein.

Both of the lugs of the bottom clamp holding the side plates were cracked. (See *Figs. 15*, *16* and *22.*)

Round 11.

Fourth shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel Harvey plate. Time, 10:23:17 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the right side of the plate.

The projectile entered and remained apparently intact in the plate, with the base 3·3 inches inside the face.

The penetration of the projectile was 20·5 inches.

A bulge was formed on the face of the plate 16·5 inches in diameter, with a broken curling fringe about the hole 2 inches high and a few radial hair cracks in the bulge about 3 inches in length.

The bulge on the back of the plate was 18 inches in diameter and 4·62 inches high about the projectile, with a star of cracks extending therefrom.

The indent on the backing was a jagged hole 12 inches in diameter corresponding to the back bulge, with the imprint of the point of the projectile 10 inches deep and two small fragments of the plate sticking therein.

(See *Figs. 17*, *18* and *22.*)

Round 12.

Fourth shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 10:30:12 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the right side of the plate.

The point of the projectile entered and remained in the plate, presenting an appearance of being welded therein, the end of the chamber being level the face of the plate. The base and body of the projectile were broken into many small fragments.

The estimated penetration of the point was 7·32 inches.

A bulge was formed on the face of the plate 13·75 inches in diameter. Near the head of the projectile the metal of the plate was dished in and scarcely distinguishable from that of the projectile remaining in the plate. A few radial hair cracks were in the bulge, of varying lengths, none over 6 inches, and a few pieces of metal were scaled off in the bulge.

The bulge on the back of the plate was nearly imperceptible, but was found to be 17 inches in diameter and 0·31 inch high.

No cracks.

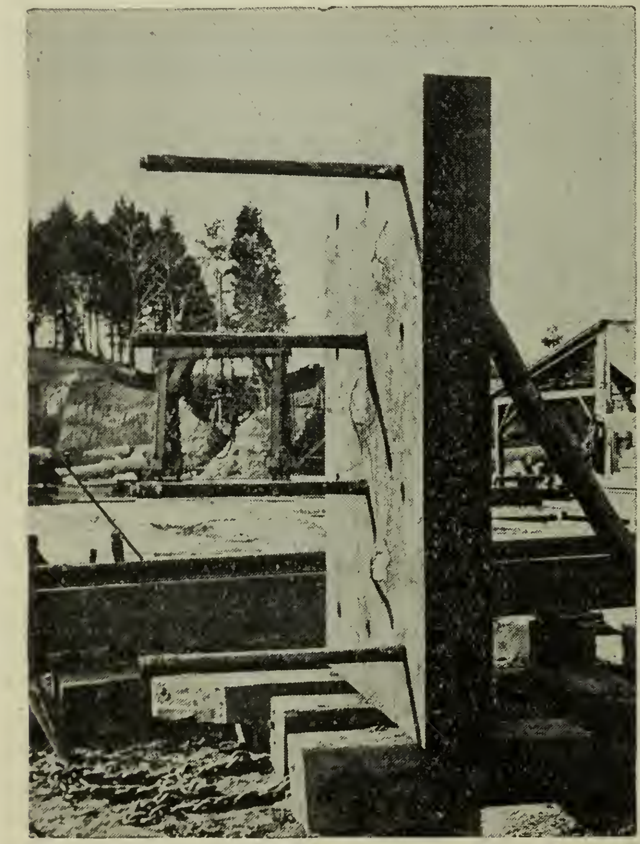

FIG. 21.—Harvey high-carbon nickel-steel, Bethlehem.

There was a discoloration of the backing opposite the back bulge, but no indent.

(See *Figs. 19, 20, 21* and *22.*)

Round 13.

Fifth shot at Carnegie, Phipps & Co.'s high-carbon nickel-steel plate. Time, 12 9:48 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Eight-inch Carpenter armor-piercing shell of 250 pounds.

The point of impact was the centre of the plate.

The projectile entered and rebounded 6 feet 3 inches to the front, very much set up and cracked. The cracks were generally longitudinal, and

The penetration of the point was 12·75 inches.

A bulge was formed on the face of the plate 16·75 inches in diameter, with a regular and curling fringe 1·75 inches high around the hole, with three radial hair cracks in the bulge, each 3 inches long.

The bulge on the back of the plate was 15 inches in diameter and 2·75 inches high, about the hole 0·5 inch wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge, and was 11 inches in diameter and 2 inches deep.

Several bolts of the side plates were started and loosened.

The top of the plate was sprung from the backing 0·75 inch.

(See *Figs. 8, 9* and *14*.)

Round 8.

Third shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel plate. Time, 10:2:32 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered and remained in the plate apparently intact. The base plug could be turned while the projectile was warm, but when cold was set fast. The base of the projectile projected 2·69 inches from the face of the plate.

The estimated penetration of the point was 14·6 inches.

A bulge was formed on the face of the plate 16·5 inches in diameter, with a regular and curling fringe about the hole 1·44 inches high.

No cracks.

The bulge on the back of the plate was 17 inches in diameter and 4·25 inches high, about the hole 2 inches wide which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 11 inches in diameter and 2·75 inches deep.

The top of the plate was sprung 0·75 inch away from the backing.

(See *Figs. 10, 11* and *14*.)

Round 9.

Third shot at Bethlehem Iron Company's low-carbon steel Harvey plate. Time, 10:10:45 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered and remained apparently intact in the plate, the base 9·68 inches inside the face.

The estimated penetration of the point was 26·96.

A bulge was formed on the face of the plate 16·25 inches in diameter, with a fringe about the hole 1·3 inches high, part of which was chipped off, and numerous radial hair cracks in the bulge not over 3 inches long.

The bulge on the back of the plate was 18 inches in diameter and 3·5 inches high about the hole through which the projectile had passed.

A crack extended from the hole to the bottom of the plate 24 inches from the left side, which probed 2·37 inches deep. The crack noted in No. 2 shot on this plate opened slightly and a surface crack developed upwards from No. 2 hole towards the top of the plate.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and 2·5 inches deep. The projectile remained in the backing, its base projecting 1·5 inches from the surface.

The lugs of the wrought-iron clamp which held the bottom of the side plates were bent outwards and the right one cracked, showing that the side plates had been forced outward at the moment of firing.

(See *Figs. 12, 13* and *14.*)

Round 10.

Fourth shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 10:18:52 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the right side of the plate.

The projectile entered, broke into several pieces and rebounded, the head being found 21 feet to the front.

The penetration of the point was 10·37 inches.

The bulge was formed on the face of the plate 17·25 inches in diameter, with a regular and curling fringe about the hole 1·87 inches high, and two radial hair cracks in the bulge 3 and 4 inches long.

The bulge on the back of the plate was 15 inches in diameter and 1·62 inches high, with a slight crack from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 10 inches in diameter and one inch deep.

The side plate bolts were started and the upper part of the plate was 0·75 inch away from the backing.

(See *Figs, 8, 9* and *14.*)

Round 11.

Fourth shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel plate. Time, 10:26:55 A. M.

Gvn.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the right side of the plate.

The projectile entered, broke into several pieces, and rebounded, the head and a portion of the body in one piece being found 29 feet 6 inches to the front and 25 feet to the right. The head parted from the body at the bourrelet for about 300° with a single piece of the body about 4 inches long adhering thereto.

The penetration of the point was 13·19 inches.

The bulge was formed on the face of the plate 17·5 inches in diameter, with a regular and curling fringe about the hole 1·75 inches high.

No cracks.

The bulge on the back of the plate was 18 inches in diameter and 2·87 inches high about the hole 2 inches wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 11 inches in diameter and 2·5 inches deep, with a small fragment of the plate sticking therein. The course of backing next to the plate was split between No. 3 and No. 4 hole.

(See *Figs. 10, 11* and *14*.)

Round 12.

Fourth shot at Bethlehem Iron Company's low-carbon steel Harvey plate. Time, 10:36:50 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the right side of the plate.

The projectile entered and remained in the plate very much set up, the base projecting 6·37 inches from the face of the plate. The projectile near the bourrelet was expanded one inch, and there were two longitudinal cracks in the body; the base plug could be easily turned.

The estimated penetration of the point was 10 inches.

A bulge was formed on the face of the plate 16·25 inches in diameter and 1·5 inches high, much of the metal about the hole being chipped off.

A crack extended from No. 3 hole to the bottom of the plate 3·75 inches from the right side, which probed from 3 to 4·5 inches deep. A second crack extended from No. 4 hole vertically downwards and joined the last. Small surface cracks 15 inches long developed from hole No. 3.

The bulge on the back of the plate was 16 inches in diameter and 2 inches high with a star or cracks opening out from the point of the projectile.

The indent of the backing corresponded in shape to the back bulge, and was 12 inches in diameter and one inch deep.

(See *Figs. 12, 13* and *14*.)

Round 13.

Fifth shot at Bethlehem Iron Company's high-carbon nickel-steel plate. Time, 1:27 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Firminy armor-piercing shell of 210 pounds. The point of impact was the centre of the plate. The projectile entered the plate and rebounded apparently intact 25 feet to the front, struck an oak timber, then ricocheted 29 feet farther, striking bank and rebounded 8 feet. It was shortened 0·12 inch, expanded at bourrelet 0·00 inch, at body 0·06 inch, at base 0·01 inch.

The penetration of the point of the projectile was 16·5 inches.

A bulge was formed on the face of the plate 20·75 inches in diameter, with a regular and curling fringe around hole 2·12 inches high. A wide crack radiated from this by No. 1 hole to the top of the plate 12·25 inches from the left-side, another through No. 3 hole to the bottom of the plate

10·12 inches from its left side, and another to the No. 2 hole, all of which extended through the plate.

The bulge on the back of the plate was 22 inches in diameter and 5·5 inches high about the ragged hole 4·5 inches wide, made by the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 15 inches in diameter and 4 inches deep, with the imprint of the point of the projectile sharply defined, 5·62 inches deep.

The entire target structure was set back about an inch, the bolts of the side plates loosened and one of the backing bolts set back 4·5 inches. The top of the plate was sprung away from the backing 0·87 inch.

When the plate was removed from the backing it held together and all the armor bolts but three were easily unscrewed.

(See *Figs. 8, 9* and *14.*)

A comparison with the Creusot nickel-steel plate tested at Annapolis in 1890 is interesting at this point.*

By comparing *Figs. 6* and *7* and *Figs. 8, 9* and *14*, it will be observed that while the Creusot plate developed no cracks, the bulges at the back were much larger, the point of the eight-inch projectile passing entirely through the body, lodging in the plate. (*Plate I.*) On the other hand the Bethlehem plate, although developing a bad through crack, showed more resistance and a remarkable amount of elasticity.

Round 14.

Fifth shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel plate. Time, 1:38:20 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Firminy armor-piercing shell of 210 pounds.

The point of impact was the centre of the plate.

The projectile entered and remained in the plate apparently intact, with its base 0·87 inch inside the face of the plate.

The estimated penetration of the point was 22·08 inches.

A bulge was formed on the face of the plate 21 inches in diameter, with a regular and curling fringe about the hole 1·87 inches high.

A through crack extended from this to No. 1 hole and thence to the top of the plate 10·5 inches from the left side.

The back of the plate showed, in addition, a through crack from No. 5 through No. 4 hole to the bottom of the plate, and a very fine crack, not through, from No. 5 through No. 2 hole to the upper edge of the plate 11 inches from the right corner.

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* The dimensions of this plate were exactly the same as those under consideration, viz: 8 x 6 feet x 10½ inches.

The bulge on the back of the plate was 24 inches in diameter and 6·5 inches high about the projectile.

The indent in the backing corresponded in shape to the back bulge, was 14 inches in diameter, and the imprint of the point of the projectile was 10·75 inches deep.

Five of the backing and one of the armor bolts were started.

When the plate was removed from the backing it held together and all the armor bolts but two were easily unscrewed.

(See *Figs. 10, 11* and *14.*)

It will be noticed that the resistance of the upper part of this plate is much less (about half) than the middle and lower parts. The probable causes of this peculiarity will be discussed further on.

Round 15.

Fifth shot at Bethlehem Iron Company's low-carbon steel Harvey plate. Time, 1:46 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Firminy armor-piercing shell of 210 pounds.

The point of impact was the centre of the plate.

The projectile perforated the plate and remained, apparently intact, in the backing, the base 22·25 inches inside the face of the plate.

The estimated penetration of the point was 43·48 inches.

A bulge was formed on the face of the plate 22·5 inches in diameter and 1·25 inches high; the metal about the hole was chipped off.

A through crack reached from No. 2 to No. 3, passing through No. 5 hole, and all the previous cracks widened and some were much extended.

The bulge on the back of the plate was 24 inches in diameter and 8·37 inches about the hole through which the projectile had passed. The back of the plate showed in addition the following cracks, which extended partly through the plate: One from No. 5 to No. 4 hole, and three from No. 1 hole, the first to the top of the plate 13·5 inches from the left side; the second to the left side, 10 inches from the top; and the third to No. 5 hole.

The imprint in the backing corresponded in shape to the back bulge, and was 15 inches in diameter. The projectile remained in the backing.

The backing was split and broken through in wake of the shot. The side plates were started away one inch at the top, and several of the backing-bolts were driven back.

When the plate was removed from the backing it held together, and ten of the armor-plate bolts could not be unscrewed.

(See *Figs. 12, 13* and *14.*)

At this point a comparison with *Fig. 5*, which shows the compound Cammell plate tested at Annapolis, 1890, would be of interest.

In the case of the compound plate we have a hard steel face *welded* to a wrought iron back and in the Bethlehem plate a hard steel face produced by a chemical (cementation) treatment of the face of a solid steel plate. The properties of the two plates are therefore more or less similar inasmuch as each has a hard steel face, but the vast superiority of one over the other is manifest. All the projectiles *perforated* the compound plate, whilst none but the eight-inch got through the Bethlehem plate.

The accompanying table shows the comparative resistance of the four nickel-steel plates, viz: Creusot (Schneider & Co.), Bethlehem, the *low-carbon*, Carnegie, Phipps & Co., and the *high-carbon*, Carnegie, Phipps & Co. The terms high- and low-carbon used here are relative, the Creusot plate being considered, the author believes, a high-carbon plate. The public were informed that "high-carbon" meant about 0·4 per cent., and "low-carbon" 0·25 per cent., the content of nickel varies from 2 to 3·5 per cent.

The low-carbon plate contained about half as much carbon as the high-carbon plate, as will be seen from the following analysis of the Carnegie, Phipps & Co. low-carbon plate:

		I.	II.
Carbon,	=	0·26	
Phosphorous,	=	0·072	0·071
Manganese,	=	0 789	—
Silicon,	=	0·050	—
Nickel,	=	2 67	2·55
Sulphur,	=	0·013	—
Specific gravity,	=	7·822	—

A comparison of the analysis of the nickel-steel deck plate on p. 427, will be of interest at this point.

It must be understood in comparing the merits of the above American plates that these trials were not intended to determine which of the two steel works could produce the best plate, but to determine what *particular kind of plate* would give the best results under the same conditions, Neither company, the author understands, is an advocate for any one particular kind of plate, but make whatever the Government specify, whether it be high- or low-carbon steel or nickel-steel, Harvey treated or Tresidder treated. The accompanying table shows the Bethlehem plate to have developed more resistance than the Creusot plate, although the latter showed no cracks at the end of the trials. The penetrations and back bulges were as regular on one plate as on the other, showing the relative resistance of the different parts of each plate to have been fairly uniform. The Carnegie plate showed unmistakable evidences of a comparative softness at the top where, rather strangely, after the fifth shot its only through crack was developed.

Another point in favor of this Bethlehem plate should be taken in consideration. The Bethlehem Iron Company were not only inexperienced in the manufacture of armor-plates, but these Indian Head trials were much more severe on the plates than were the Annapolis trials of 1890, while most of the conditions were the same, they differed in one very important particular, viz: the interval of time between the firing of the six-inch and the eight-inch shots. It is well known to physicists and engineers that when severe strains have been set up in large masses of metal they can be very sensibly reduced by allowing the metallic mass to remain perfectly quiet and free from strains for a considerable interval of time. If this theory be correct, and the author has no doubt that it is, it would be only reasonable to expect that the strains set up by firing a six-inch projectile into each of the four corners of a plate would be materially reduced by allowing the plate to stand several days before an eight-inch projectile was fired into the centre. This was the case at the Annapolis trials, when an interval of two days elapsed between the firings of the six-inch and eight-inch projectiles. At the Indian Head trials, however, this interval was about two hours, and the author feels quite certain that the metal in the plates had not even reached its normal temperature before the eight-inch projectiles were fired.

The author called attention to this fact (*i. e.*, he believes it to be a fact) a few days after the first of these trials,* and has since had no reason to change his views.

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* The *Bulletin Am. Iron and Steel Association*, November 11, 1891, p. 329.

SECOND DAY, NOVEMBER 14, 1891.

Weather clear. Thermometer at 9 A. M. 49° F.; at 1 P. M., 69° F.

Round 1.

First shot at Carnegie, Phipps & Co.'s high-carbon nickel-steel plate. Time, 9:8:30 A. M.

Gun —Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered and rebounded 46 feet 6 inches to the front, burying itself in the sand. A circumferential hair crack was found near the bourrelet and the projectile was shortened 0·1 inch and expanded at bourrelet 0·0 inch, at body 0·04 inch, at base 0·0 inch.

The penetration of the point of the projectile was 12·5 inches.

A bulge was formed on the face of the plate 18·5 inches in diameter, with a chipped fringe 2 inches high about the shot hole, and a number of radial hair cracks in bulge not exceeding 3 inches long.

The bulge on the back of the plate was 14·5 inches in diameter and 3·56 inches high about the hole, 2·5 inches wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 13 inches in diameter and 2·62 inches deep.

Two of the side-plate bolts were started.

(See *Figs. 15*, *16* and *22*.)

Judging from the effect of the projectiles, the amount of carbon in this plate must have been much greater than the the other two nickel-steel plates.

By comparing *Fig. 6* with *Figs. 8* and *10*, it will be noted that there is an extensive fringe around each of the points of impact in Bethlehem and Carnegie, Phipps & Co. low-carbon nickel-steel plates, showing the metal to be ductile and elastic. The Creusot plate of the Annapolis trials, however, resembled the Carnegie, Phipps & Co. high-carbon nickel-steel plate under consideration more in this particular. The metal, instead of curling up in a regular fringe, chipped and flaked off like the excessively hard face of a Harvey-treated or compound plate.

Round 2.

First shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel Harvey plate. Time, 9:18:20 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered and remained apparently intact in the plate, the base projecting 2·62 inches from the face of the plate, the axis slightly inclined from the normal. A very small piece was found broken off from the extreme point of the projectile and two flakes were started from the head, half-way between the point and the bourrelet, adhering firmly at their rear ends.

The penetration of the projectile was 14·6 inches, the axis slightly inclined to the normal.

A bulge was formed on the face of the plate 18 inches in diameter, with a chipped fringe about the projectile 2·37 inches high, and a number of radial hair cracks in the bulge not over 4 inches long.

The bulge on the back of the plate was 21·5 inches in diameter and 4·12 inches high, with a star of cracks opening from the hole 5·5 inches wide through which the point of the projectile had passed.

The indent in the backing was jagged, 4 inches deep at centre and 14 inches in diameter. A small fragment of the plate adhered thereto.

One of the side-plate bolts was started.

(See *Figs. 17, 18* and *22.*)

A through crack developed at this point after the fifth shot.

Round 3.

First shot at Bethlehem Iron Company's high-carbon nickel-steel Harvey plate. Time, 9:26:56 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the left side of the plate.

The projectile entered the plate, broke into 3 pieces, and rebounded, the largest piece being found 45 feet to the front and 10 feet 6 inches to the right. One piece was the point 3 inches long, another, longitudinal, extending from the base 7 inches and 5 inches wide; the remaining piece was somewhat cracked. The projectile was expanded at bourrelet 0·03 inch.

The penetration of the point was 12 inches.

A bulge was formed on the face of the plate 18·25 inches in diameter with a chipped fringe about the hole 1·12 inches high, and a number of radial hair cracks in the bulge not over 5 inches long.

The bulge on the back of the plate was 21 inches in diameter, and 2·25 inches high about the hole 0·25 inch wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and 1·5 inches deep.

The head of one of the side plate bolts was broken and two others loosened.

(See *Figs. 19, 20, 21* and *22.*)

Round 4.

Second shot at Carnegie, Phipps & Co.'s high-carbon nickel-steel plate. Time, 9:38 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the right side of the plate.

The projectile entered the plate, broke into many small pieces and rebounded. The head about 10 inches long was recovered, fracture jagged and parallel to the bourrelet.

The penetration of the point was 10·75 inches.

A bulge was formed on the face of the plate 19·75 inches in diameter with a curling fringe, partly chipped off about the hole 1·56 inches high, and a few radial hair cracks in the bulge not over 3 inches long.

The bulge on the back of the plate was 15 inches in diameter, and 1·94 inches high about the hole 1·25 inches, which opened out with a star of cracks from the point of the projectile. Three large pieces of the bulge were broken off.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and 1·62 inches deep. A fragment of the plate 9 x 4 x 2·5 inches adhered to the backing.

(See *Figs. 15*, *16* and *22*.)

Round 5.

Second shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel Harvey plate. Time, 9:41:15 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the right side of the plate.

The projectile entered and remained apparently intact in the plate, the base projecting 2·44 inches from the face of the plate, the axis slightly inclined to the normal.

The estimated penetration of the point was 14·86 inches.

A bulge was formed on the face of the plate 15 5 inches in diameter, with a ragged fringe about the hole 2 inches high and a number of radial hair cracks in the bulge not over 4 inches long.

A bulge on the back of the plate was 22 inches in diameter and 4·75 inches high about the hole 5·12 inches wide, which opened out with a star of deep cracks from the point of the projectile.

The indent in the backing was jagged, corresponding in shape to the back bulge, 11 inches in diameter and 4 inches deep. The course of the backing next to the plate was split between shot holes No. 1 and No. 2.

One of the side plate bolts was started.

(See *Figs. 17*, *18* and *22*.)

Round 6.

Second shot at Bethlehem Iron Company's high-carbon nickel-steel Harvey plate. Time, 9:48:40 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the top and 24 inches from the right side of the plate.

The point of the projectile entered and remained in the plate, presenting an appearance of being welded therein, the end of the chamber 0·5 inch outside of the plate; the body and base were broken into many small fragments, none of which were recovered.

The estimated penetration of the point was 6·82 inches.

A bulge was formed on the face of the plate 12·75 inches in diameter. Near the head of the projectile the metal of the plate was dished in and scarcely distinguishable from that of the projectile remaining in the plate. A few short radial hair cracks were in the bulge.

The bulge on the back of the plate was nearly imperceptible, but was found to be 18 inches in diameter and 0·25 inch high.

No cracks.

There was a discoloration of the backing opposite the back bulge but no indent.

A head of one of the side plate bolts was broken.

(See *Figs. 19, 20, 21* and *22.*)

Round 7.

Third shot at Carnegie, Phipps & Co.'s high-carbon nickel-steel plate. Time, 9:55:40 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered the plate and rebounded, broken into several large and a number of small pieces; some of the former recovered, among which was half of the head, which had been split longitudinally.

The penetration of the point was 12 inches.

A bulge was formed on the face of the plate 19·25 inches in diameter, with an irregular curling fringe partly chipped off about the hole 1·75 inches high, and a few radial hair cracks in the bulge.

A through crack extended from this hole to the bottom of the plate 28·75 inches from the left lower corner, which was sprung out about 0·5 inch.

The bulge on the back of the plate was 16 inches in diameter and 2·37 inches high about the hole 2 inches wide, which opened out with a star of cracks from the point of the projectile; about half of the bulge was broken out to a depth of about 1·5 inches.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and 2·5 inches deep. One small fragment of the plate was imbedded in the backing.

(See *Figs. 15, 16* and *22*)

Round 8.

Third shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel Harvey plate. Time, 10:2:15 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered the plate and rebounded to the front 12 feet 6 inches, and thence ricocheted 35 feet 2 inches beyond. It was considerably upset, being shortened 2·09 inches and expanded at the bourrelet 0·86 inch, at the body 0·58 inch, and at the base 0·01 inch. A number of small thin pieces flaked off the head.

The penetration of the point was 9·75 inches.

A bulge was formed on the face of the plate 16·75 inches with an irregular, ragged, curling fringe 2·25 inches high about the hole and a number of radial hair cracks in the bulge not over 4 inches long.

The bulge on the back of the plate was 19·5 inches in diameter and 1·81 inches high about the hole 1·25 inches wide,which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge, and was 11 inches in diameter and 1·37 inches deep.

(See *Figs. 17, 18* and *22.*)

Round 9.

Third shot at Bethlehem Iron Company's high-carbon nickel-steel Harvey plate. Time, 10:9:30 A. M.

Gun.—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from the left side of the plate.

The projectile entered the plate and rebounded 37 feet 10 inches to the front and thence ricocheted 19 feet farther. The projectile was unbroken, but there was a longitudinal crack from bourrelet to band score. It was shortened 0·14 inch and expanded at bourrelet 0·015 inch, at body 0·05 inch, at base 0·01 inch.

The penetration of the point was 12·25 inches.

A bulge was formed on the face of the plate 18 inches in diameter, with an irregular chipped fringe about the hole 1·5 inches high, and a number of radial hair cracks in the bulge not over 5 inches long. There were also three deeper radial cracks—two 6 inches, and one 5·5 inches long.

The bulge on the back of the plate was 15·25 inches in diameter and 2·12 inches high near the hole one inch wide which opened out with a star of racks from the point of the projectile.

The indent in the backing corresponded in shape to the back bulge and was 12 inches in diameter and 1·25 inches deep.

One of the backing bolts was started back 1·5 inches.

(See *Figs. 19, 20, 21* and *22.*)

Round 10.

Fourth shot at Carnegie, Phipps & Co.'s high-carbon nickel-steel plate. me, 10:16:50 A. M.

Gun—Six-inch B. L. R.

The point of impact was 24 inches from the bottom and 24 inches from he right side of the plate.

The projectile entered the plate and rebounded 47 feet 10 inches to the front; in it were two longitudinal cracks, one from the bourrelet to the base apparently a through crack, and the other extending from the bourrelet to the band score.

many thin pieces flaked off from the head. The projectile was very hot and was still warm an hour after. It was shortened 3·58 inches, and expanded at bourrelet 1·65 inches, at the body 0·97 inch, at the base 0·28 inch.

The penetration of the point was 9·62 inches.

A bulge was formed on the face of the plate 20 inches in diameter, with an irregular fringe about the hole 1·75 inches high and a few radial hair cracks in the bulge.

A through crack extended from the No. 3 through No. 5 and No. 2 holes to the right side of the plate, 7 inches from the top, and those developed at No. 3 and No. 4 shots were somewhat opened.

In addition to the through cracks on the face of the plate, the following, extending nearly through the plate, were found on the back: One from No. 5 through No. 1 hole to the top of the plate, 15·5 inches from the left upper corner, and one from No. 4 hole to the right side of the plate 18 inches from the right lower corner.

The bulge on the back of the plate was 25 inches in diameter and 1·56 inches high, about the hole 1·25 inches wide, which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded to the back bulge and was 13 inches in diameter and one inch deep.

The middle armor bolt of the second row from the bottom was broken at the plate and thrown 2 feet to the rear; both of the lugs of the bottom clamp for the side plates were broken. The backing structure was set back 0·5 inch, and the course of backing next to the plate was split.

When the plate was removed from the backing the left lower corner separated from the remainder of the plate. The armor bolt above No. 5 hole stuck in the plate; the one below it was broken off flush with the back of the plate; the remaining bolts were easily unscrewed.

The top of the plate was after the firing sprung 0·25 of an inch away from the backing.

(See *Figs. 15, 16* and *22.*)

This was the first time American projectiles were used at these trials, and it must in truth be admitted they were not up to the standard. Any one familiar with the subject knows how difficult it is to make an efficient a. p. projectile, and it can hardly be expected that the Carpenter Steel Company, having so recently domesticated the Firminy process at their works at Reading, Pa., could produce, with such a short experience, results as good as those produced abroad after years of trial and experiment

The fact the projectile was so hot after striking the plate, shows very conclusively that a very large proportion of the work was expended upon it instead of the plate, as should be the case with the best projectiles.

Round 14.

Fifth shot at Carnegie, Phipps & Co.'s low-carbon nickel-steel Harvey plate, Time, 12:19:50 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Eight-inch Carpenter armor-piercing shell of 250 pounds.

The point of impact was the centre of the plate.

The projectile entered the plate, rebounded 33 feet to the front, broke into several pieces, the head being thrown 22 feet 10 inches to the front, and the body 33 feet to the right. The extreme point of the head was bruised and a piece chipped off.

The penetration of the point of the projectile was 17·25 inches.

A bulge was formed on the surface of the plate 18·5 inches in diameter, with an irregular broken fringe about the hole 2·5 inches high, and a few radial hair cracks in the bulge.

Through cracks extended from hole No. 5 through No. 1 to the top of the plate, 6·75 inches from the left upper corner; and through No. 3 to the bottom of the plate, 11 inches from the left lower corner; a deep crack extended from No. 5 to No 2 hole.

In addition to the through cracks on the face of the plate a crack reaching nearly through the plate extended on the back from No. 5 through No. 4 hole to the bottom of the plate, 14·25 inches from the right lower corner.

The bulge on the back of the plate was 26 inches in diameter and 6·75 inches high at the hole, 5·5 inches wide, which opened out with a star of cracks from the point of the projectile.

There was a jagged depression in the backing 16 inches in diameter and 5·5 inches deep, with a small fragment of the metal sticking therein. The course of the backing next to the plate was split in the line of the upper backing-bolts.

When the plate was removed from the backing it held together, and the bolts were easily unscrewed, excepting the one above and the one below No. 5 hole.

The top of the plate was, after the firing, sprung 0·25 inch away from the backing.

(See *Figs. 17, 18* and *22.*)

Round 15.

Fifth shot at Bethlehem Iron Company's high-carbon nickel-steel Harvey plate. Time, 12:37:33 P. M.

Gun.—Eight-inch B. L. R.

Projectile.—Eight-inch Firminy armor-piercing shell of 210 pounds.

The point of impact was the centre of the plate.

The projectile entered the plate and rebounded to the front 38 feet, then ricocheted violently against the timber protection of the gun, rebounding therefrom 6 feet. The projectile cracked longitudinally and flaked consider-

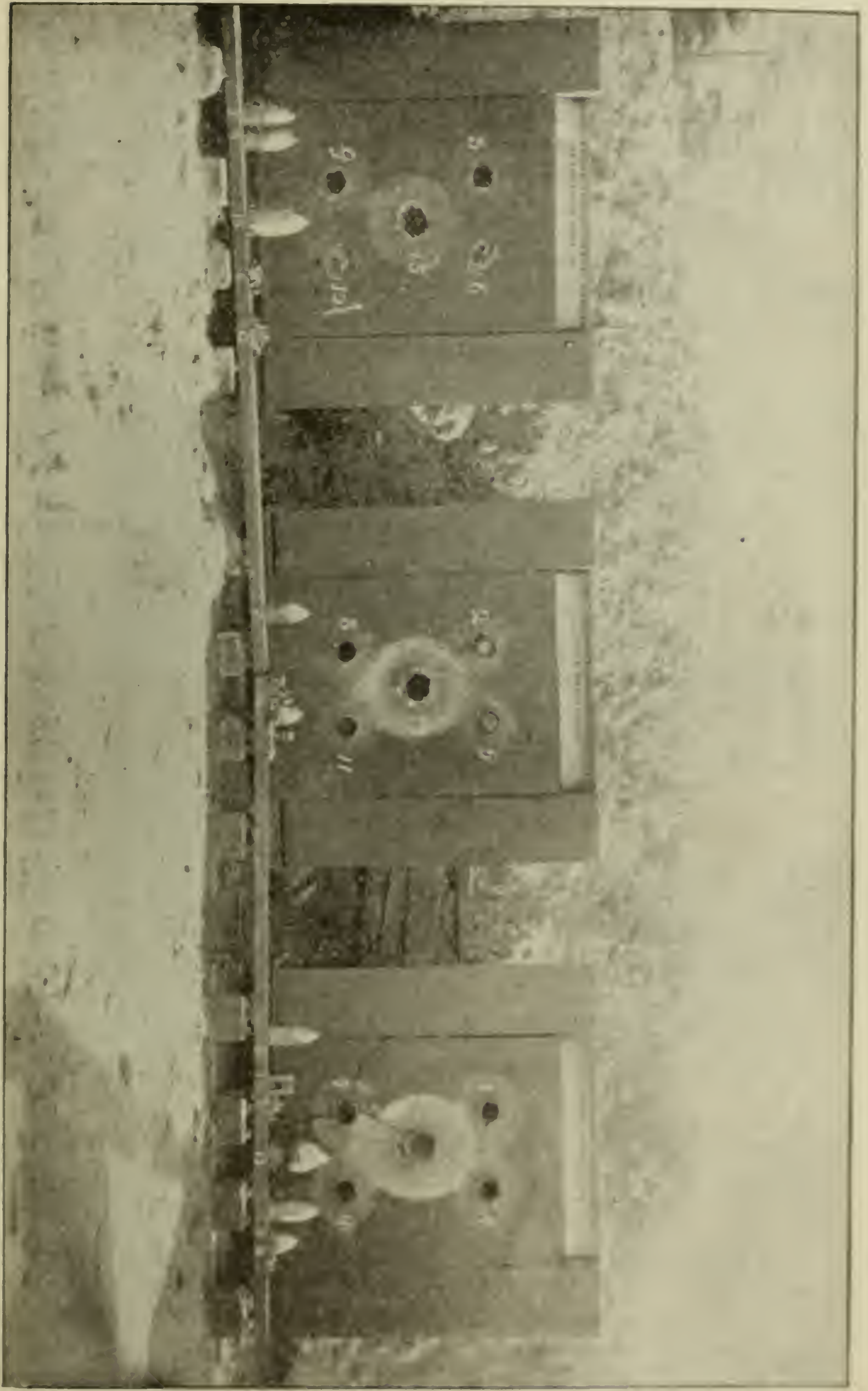


FIG. 22.—Targets after Round 15. (Second day, November 14, 1891.)

ably at the rear of the head. On the body of the shell was a score which extended around the projectile at the section of a plane inclined to the axis.

This score could have been formed by a rotary motion against a hard point, combined with a movement forward and back, and possibly was so done by the rotation of the projectile on entering and rebounding from the plate. The projectile was shortened 1·36 inches, and expanded at the bourrelet 0·31 inch, at the body 0·41 inch, at the base 0·03 inch.

The penetration of the point was 12·87 inches.

A bulge was formed on the face of the plate 17 inches in diameter, with the fringe around the hole chipped off and nowhere higher than 0·94 inch, and a number of radial hair cracks in the bulge, none over 7 inches long.

A through crack extended through hole No. 1 to the top of the plate 14 inches from the left upper corner, and another through hole No. 3 to the bottom of the plate 17·5 inches from the left lower corner.

The bulge on the back of the plate was 23 inches in diameter and 2·62 inches high about a hole 0·5 inch wide which opened out with a star of cracks from the point of the projectile.

The indent in the backing corresponded to the back bulge and was 15 inches in diameter and 2 inches deep.

The course of backing next to the plate was split in line of backing bolts. The lugs of the lower side-plate clamp were cracked and the left side plate was moved 0·25 inch to the left.

When the plate was removed from the backing it held together, and all the bolts were easily unscrewed excepting four, one above and one below No. 5 hole, and one at upper and one at lower left corner.

(See *Figs. 19*, *20*, *21* and *22*.)

SUMMARY.

After careful consideration of the results of the firing upon the six plates, it is the unanimous decision of the Board that they be placed in the following order of merit, viz:

(1) The high-carbon nickel-steel Harvey plate furnished by the Bethlehem Iron Company.

(2) The high-carbon nickel-steel plate furnished by the Bethlehem Iron Company.

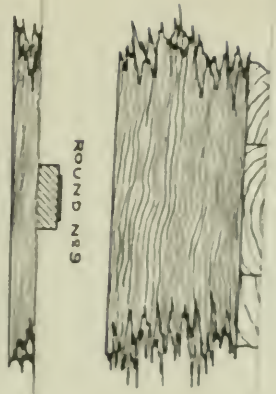
(3) The high-carbon nickel-steel plate furnished by Carnegie, Phipps & Co.

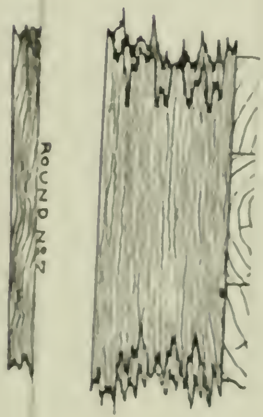
(4) The low-carbon nickel-steel Harvey plate furnished by Carnegie, Phipps & Co.

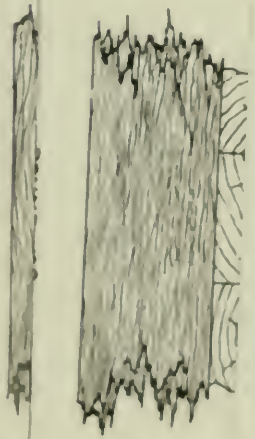
(5) The low-carbon nickel-steel plate furnished by Carnegie, Phipps & Co.

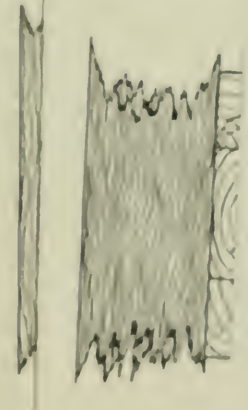
(6) The low-carbon steel Harvey plate furnished by the Bethlehem Iron Company.

The right side of the plate No. 1 showed very remarkable qualities. The two projectiles which struck that side penetrated not more than 7 inches, the head remaining in the plate completely filling the hole, and with the appear-









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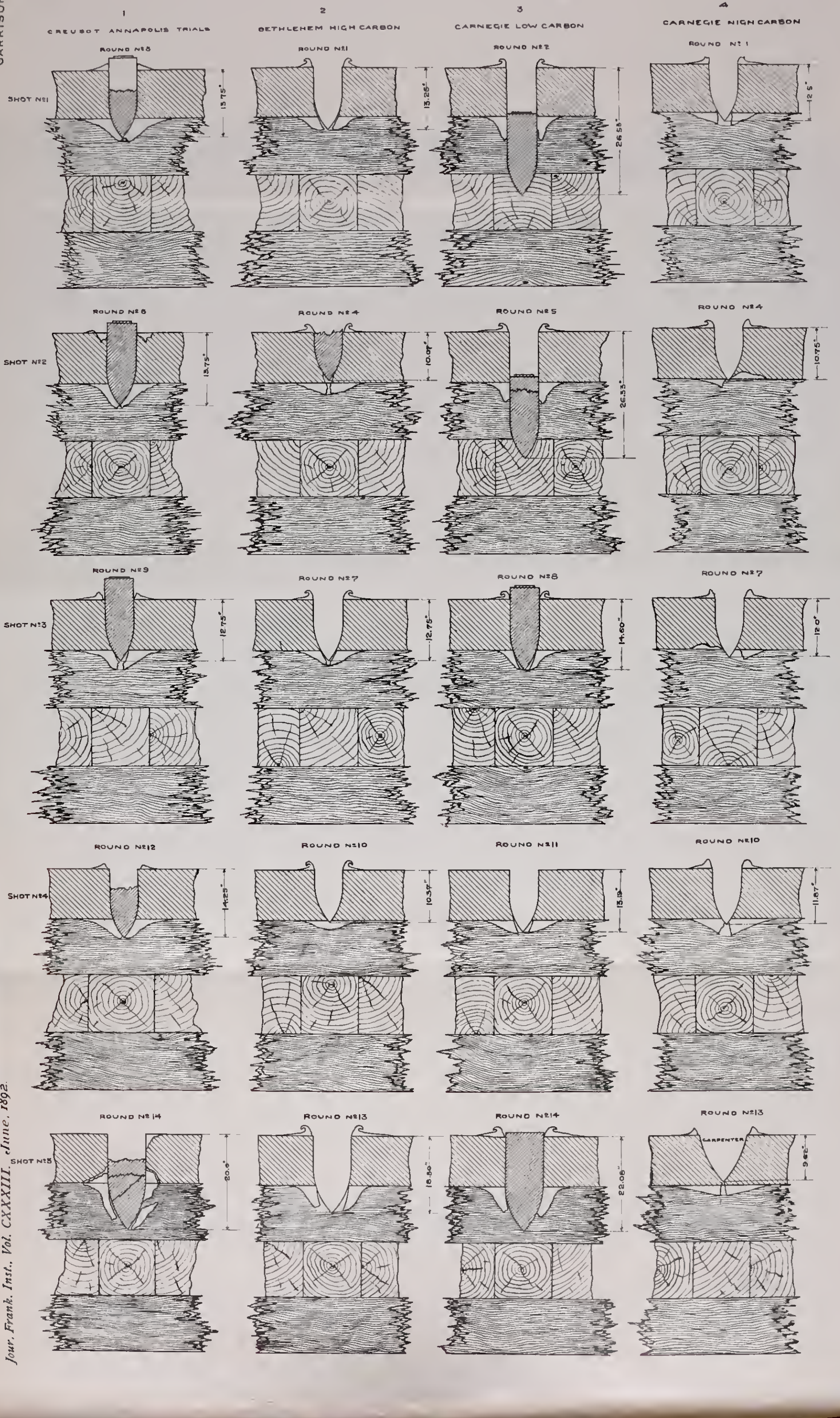
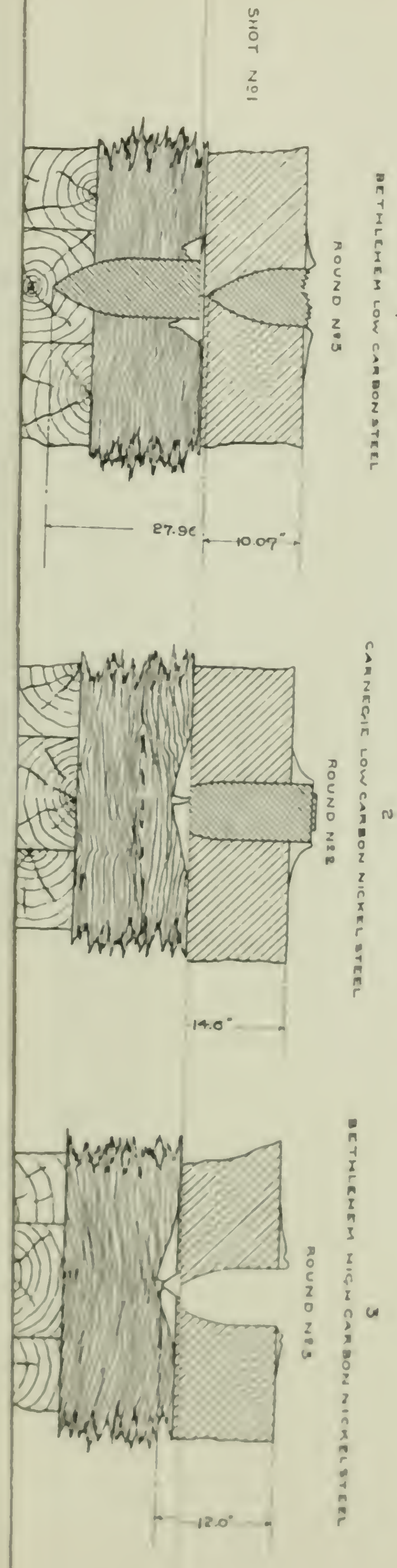
Jour. Frank. Inst., Vol. CXXXIII. June, 1892.

GARRISON

PENETRATIONS NICKEL STEEL PLATES




SHOT N°1
1
BETHLEHEM LOW CARBON STEEL
ROUND N°5
27.96
10.07"
2
CARNEGIE LOW CARBON NICKEL STEEL
ROUND N°8
14.0"
3
BETHLEHEM HIGH CARBON NICKEL STEEL
ROUND N°3
12.0"

PENETRATIONS HARVEY-TREATED PLATES

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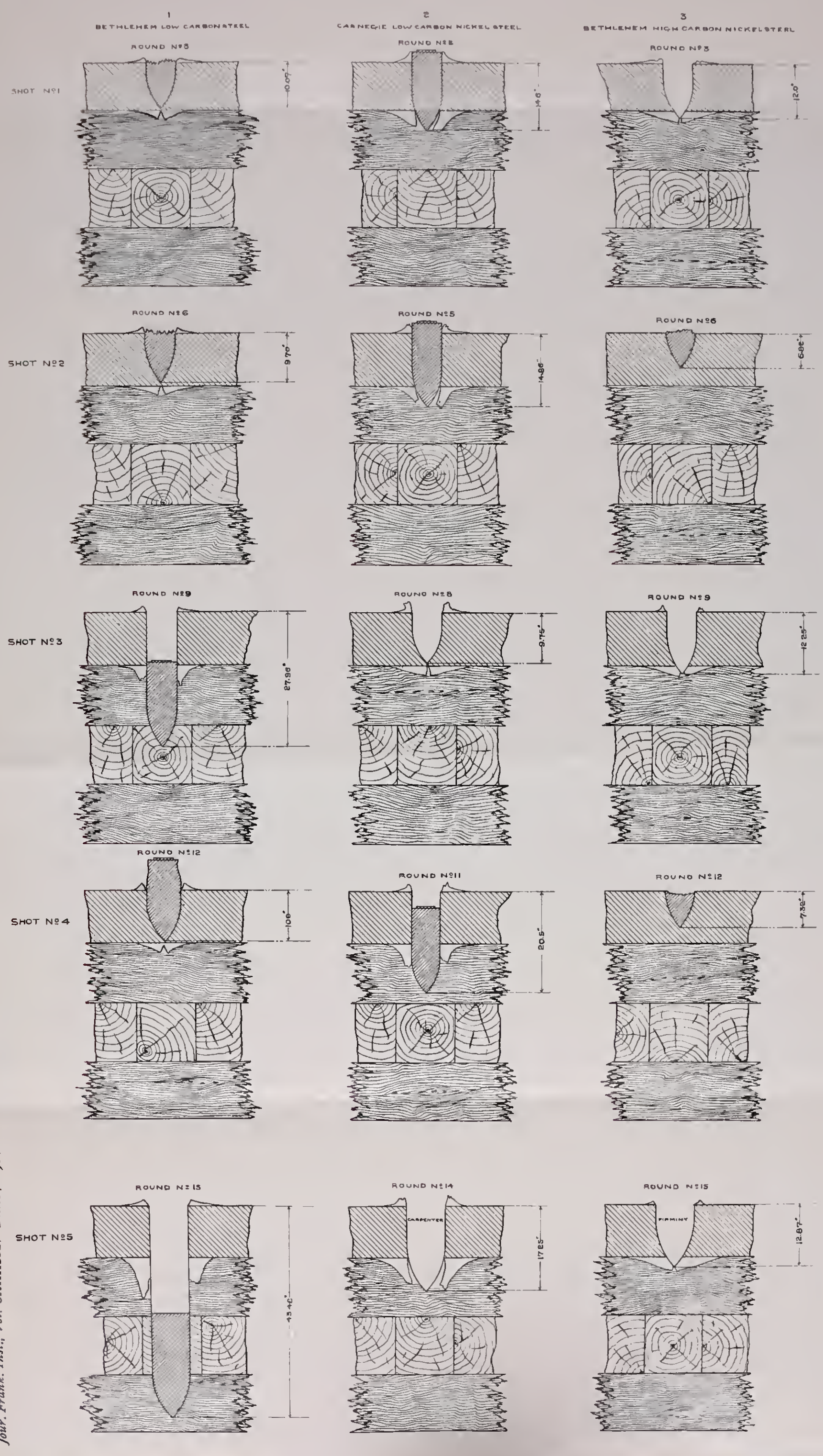
GARRISON

PENETRATIONS HARVEY-TREATED PLATES



	Eight-inch
Fourth.	*Fifth.*
C 4 inches high and inches diameter.	A crater formed 21 inches diameter.
Be 62 inches high and inches diameter.	5·5 inches high and inches diameter.
Ca 87 inches high and inches diameter.	6·5 inches high and 24 inches diameter.
C 87 inches high and inches diameter.	1·56 inches high and 23 inches diameter.

	Eight-inch.
Fourth.	*Fifth.*
Be 2 inches high and inches diameter.	Projectile through hole, 24 inches diameter.
Ca 62 inches high and inches diameter.	6·75 inches high and 20 inches diameter.
P 71 inch high and inches diameter.	2·01 inches high and 23 inches diameter.

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NICKEL-STEEL PLATES

NAME OF PLATE	PENETRATION OF POINT IN INCHES.					BULGE AT BACK.				
	No. of Six-inch Projectiles.				8-inch	No. of Six-inch Projectiles.				Eight-inch.
	First.	*Second.*	*Third.*	*Fourth.*	*Fifth.*	*First.*	*Second.*	*Third.*	*Fourth.*	*Fifth.*
Creusot nickel-steel (Annapolis trials, 1890),	13·75	13·75	12·75	14·25	20·0	5 inches high and 21 inches diameter.	6 inches high and 21 inches diameter.	4 inches high and 19 inches diameter.	4 inches high and 18 inches diameter.	A crater formed 21 inches diameter.
Bethlehem nickel-steel plate, high-carbon,	13·25	10·07	12·75	10·37	16·50	1·75 inches high and 16·5 inches diameter.	2·12 inches high and 17 inches diameter.	2·75 inches high and 15 inches diameter.	1·62 inches high and 15 inches diameter.	5·5 inches high and 22 inches diameter.
Carnegie, Phipps & Co., nickel-steel plate, low-carbon,	26·53	26·33	14·60	13·19	22·08	4·87 inches high and 16·5 inches diameter.	4·5 inches high and 17 inches diameter.	4·25 inches high and 17 inches diameter.	2·87 inches high and 18 inches diameter.	6·5 inches high and 24 inches diameter.
Carnegie, Phipps & Co., nickel-steel plate, high-carbon,	12·5	10·75	12·0	11·87	9·62[*]	3·56 inches high and 14·5 inches diameter.	1·94 inches high and 15 inches diameter.	2·37 inches high and 16 inches diameter.	2·87 inches high and 20 inches diameter.	1·56 inches high and 25 inches diameter.

[*] Carpenter a. p. projectile.

STEEL AND NICKEL-STEEL PLATES—TREATED BY HARVEY PROCESS.

NAME OF PLATE.	PENETRATION OF POINT IN INCHES.					BULGE AT BACK.				
	No. of Six inch Projectiles.				8-inch	No. of Six-inch Projectiles.				Eight-inch.
	First.	*Second.*	*Third.*	*Fourth.*	*Fifth*	*First.*	*Second.*	*Third.*	*Fourth.*	*Fifth.*
Bethlehem low-carbon steel. Harvey plate,	10·07	9·7	26·96	10·	43·48[*]	2 inches high and 16 inches diameter.	1·62 inches high and 18 inches diameter.	3·5 inches high and 18 inches diameter.	2 inches high and 16 inches diameter.	Projectile through hole, 24 inches diameter.
Carnegie, Phipps & Co., low-carbon, *nickel-steel*, Harvey plate,	14·6	14·86	9·75	20·5	17·25[†]	4·12 inches high and 21·5 inches diameter.	4·75 inches high and 22 inches diameter.	1·81 inches high and 19·5 inches diameter.	4·62 inches high and 18 inches diameter.	6·75 inches high and 26 inches diameter.
Bethlehem high-carbon, *nickel-steel*, Harvey plate,	12·	6·82	12·25	7·32	12·87[‡]	2·25 inches high and 21 inches diameter.	0·25 inch high and 18 inches diameter.	2·12 inches high and 15·25 inches diameter	0·31 inch high and 17 inches diameter.	2·62 inches high and 23 inches diameter.

[*] Firminy a. p. shell (210 pounds).

[†] Carpenter a. p. shell (250 pounds).

[‡] Firminy a. p. shell (210 pounds).

All the six-inch shells, Holtzer a. p. chrome ance of having been welded to the surrounding metal, while the body was shattered into many fragments

No cracks were made on that side of the plate.

The back of the plate on that side showed no disturbance except a hardly noticeable swelling on the surface.

It is to be noted that the upper part of plate No. 6 (Harveyed) showed qualities resembling those of the right side of No. 1, while, on the other hand, plate No. 4 (likewise Harveyed) was totally lacking in such characteristics.*

Plate No 2 showed a great degree of uniformity as well as resistance to penetration.

The small penetration of the eight-inch shot in plate No. 3 is, in the opinion of the Board, due to the excessive upsetting of the projectile.

All of the armor-plates were more or less cracked through, but only two, Nos. 3 and 6, badly, and these two plates alone showed cracking before the fifth shot. Plates Nos. 1, 2 and 3 kept out all the projectiles; No 4 was perforated by one, and Nos. 5 and 6 by two projectiles each.

It will be noticed that the "high carbon" plates show better results than those of "low-carbon," but it is believed that the chemical anaylsis of the plates now in progress will show that the words "high" and "low," employed by the manufacturers, have been used arbitrarily and have but little value for purposes of comparison.

The Holtzer and Firminy projectiles were part of the lot used at the Annapolis armor trials of last year.

Comparing the plates of this trial with the Creusot steel and the Creusot nickel-steel plates of the Annapolis trials of September, 1890, the Board is of the unanimous opinion that—

No. 1, the high-carbon nickel-steel Harvey plate furnished by the Bethlehem Iron Company, and

No. 2, the high-carbon nickel-steel plate furnished by the Bethlehem Iron Company, are superior to the Creusot steel and nickel-steel plates of last year.

The following tables show the relative penetrations of the projectiles in the nickel-steel plates and in the several plates treated by the Harvey process.

In accompanying *Plates I* and *II*, we have these penetrations graphically illustrated. The penetrations in the Creusot nickel-steel plate of the Annapolis trials of 1890 are included.

[*To be continued.*]

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* The method of tempering at Bethlehem differed from that at Pittsburgh. [Note by Department authority.]

EYESIGHT, IN MIDDLE LIFE AND OLD AGE, WITH A FEW HINTS FOR ITS CARE AND PRESERVATION.

BY L. WEBSTER FOX, M.D.

[*A lecture delivered before the Franklin Institute.*]

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Little more than a year ago I had the honor of appearing before the members of the Franklin Institute and their friends, to lecture on a subject of great importance to the growing child and youth.

The widespread interest which this lecture created not only in this country but abroad, its republication in scientific and abstracts from it by medical journals, has led me to think that that lecture has not been without its good results.

In that lecture I dealt with the care of vision during infancy and led up to adult life. Having considered these two periods and called attention to whatever may prove either injurious or beneficial to the eye, I now take up the thread of my discourse, and continue it up to old age.

If the eye of man has escaped the vicissitudes of youth, we find it at its best at about twenty years of age. Let the boy be brought up strong in mind and with a clear intellect, so that when he enters his twenty-first year he will have the physique to carry him through the life work which lies before him.

In this day of telegraphy, shorthand and specialism, man has much labor both mentally and physically to perform, and we must always remember that 'tis through the eye that the greater part of this labor is accomplished.

It is bound to excite astonishment at the wonderful labor-performing functions of an eye when we think of what can be done. The expenditure of eyesight means also the necessity of recuperation of the functions of the eye. If these functions are blunted by some toxic drug, the vision must necessarily become weakened and in some instances destroyed.

"Habit," says Schiller, "is the nurse of man." If boys bring with them up to the entrance of manhood habits which are pernicious, what a serious outlook for the lasting qualities of that individual who requires immense expenditure of nervous energy and eyesight between manhood and old age, or between twenty and sixty.

Some of you may remember that I closed my last lecture by suggesting some hints on the care of vision, and called attention to the habit of smoking, particularly. Tobacco and alcohol are the two most prominent agents which not only pervert but also destroy special senses, and of which men of this age too freely indulge, especially in social life. How guarded should the young man be that he does not fall into habits which cling to him through life like a leech!

It is a well authenticated fact that boys who have indulged in the use of tobacco are not mentally and physically as strong as those who abstain; not only have medical men recognized the tendency to a depression of the vital force in boys and young men who are constant users of tobacco, but athletic trainers will never select their boats' crew from such ranks.

These men know that tobacco weakens the heart. It is the same with foot-ball teams, or tug-of-war men; they may be giants of strength, but when the final test comes, that subtle fluid flying through their nerves with lightning-like rapidity, is suddenly snapped; collapse and defeat follow.

When such facts are known to non-medical men, no wonder that twenty-nine States have passed laws forbidding the sale of tobacco to boys.

I do not wish in a public lecture of this kind to speak of a great benefactor, but I must say that if any one man deserves the thanks of a generation, it is John H. Fow, of this city, for bringing about the law prohibiting the sale of cigarettes to boys.

The excessive use of tobacco not only weakens the muscles of the eye, but also produces a lowering of the acuity of vision and a form of color-blindness. I can recall an instance of this peculiar form of blindness.

Prof. Chisolm, of Baltimore, some years ago had a patient, a planter's wife from one of the Southern States, consult him for defective vision, and who was also blind to certain colors. Prof. Chisolm, after making an examination with the ophthalmoscope, and who up to this stage of the examination had not asked her anything as to personal habits, turned to her and said, "If you were a man I should pronounce your case one of tobacco amblyopia, or color-blindness due to excessive use of tobacco." The lady, completely surprised at the keenness of the observation, confessed that she was an excessive smoker; she and her husband lived alone in a retired part of the country, and in the evening after dinner she would light her husband's pipe, at first taking but one whiff; as time went on she would increase the number of whiffs, until she gradually became addicted to the use of tobacco.

How often we hear of the sudden deaths of young men or individuals in the prime of life! Could we read between the lines, or in other words dissect that nervous system, we might read there, or find the evidence of over-indulgence in tobacco.

Dr. Martin, of Manchester, writes: "The injurious effects of smoking may not, except under very careful testing, become apparent for years. In many cases it may be difficult to prove that certain diseased conditions are chiefly or wholly attributable to smoking, but where our knowledge of disease processes is very exact, and especially where we have undoubted methods of testing the symptoms presented, the proof of the adverse action of a particular agent may be proved beyond doubt."

With smoking, I class the chewing of tobacco as a very grave evil. The filthy habit which compels street-car companies to exhibit placards in their cars prohibiting spitting, speaks in words stronger than I can use. It is a disgrace to American manhood that such a recourse had to be taken.

We read that Prof. Pfeiffer has discovered the bacillus of influenza in sputum. Is it surprising that influenza exists in this city when every street pavement or public building is one large cuspidore?

Let any one take a walk down Broad Street on a Sunday afternoon, or pass through the archways of our Public Buildings, and it makes one wish that we had a law prohibiting the sale and use of chewing tobacco and expectorating in public places. The chewing of tobacco as an indirect destroyer to vision ranks second to smoking, and every boy should be severely punished for using it.

One thing to which attention has been recently called is that the women of this generation are proportionately larger than men. If such is the fact may it not be due to women abstaining from the use of tobacco?

Large sums of money are voted and many laws passed for all kinds of sanitary precautions; medical colleges vie with each other in selecting the ablest and best instructors to guide medical students towards becoming the keen guardians of the public health, but what does it avail when these patent evils remain unfettered! Do not misunderstand my imputations against the use of tobacco; a large gulf lies between the use and abuse of the fragrant weed. Men who have gone through a certain amount of mental strain are the better for smoking one, two or three cigars daily; they have a soothing effect upon the over-wrought nervous system, and smoking brushes away the cobwebs and makes man a more sociable creature. Any excessive indulgence in smoking is sure to produce evil results, but the chewing of tobacco must be condemned at all times.

Another source of injury to vision is the excessive use of alcohol in whatever form it is taken into the system. The drinking of beer or wine acts in a deleterious manner upon that part of the eye called the crystalline lens.

Excessive wine and beer drinkers are very prone to have cataracts before they have passed the forty-fifth mile-post in their lives, while whiskey drinkers are subject to affections of the retina and optic nerve.

There are also certain drugs which produce a bad effect on vision. It is said that Americans are fast becoming a quinine-eating people. I do not wish for a moment to speak against any drug so important to the pharmacopoeia, but I must enter my protest as an ophthalmic surgeon to the indiscriminate use and abuse of this valuable therapeutic agent.

I am sure that certain intraocular affections may be traced to the abuse of this drug. I have in my possession the notes of several cases where blindness was directly traced to excessive doses taken at short intervals.

One of these patients had a very sad ending. This man spent several months in the Valley of the Amazon, and while there contracted ague. To break up the severe attacks of chills and fever, he was obliged to literally feed upon quinine. He continued this treatment until his eyesight began to fail, when, upon his return to this country, he consulted me about his blindness, but was already beyond ophthalmic aid. I could continue this chapter on the abuse of this invaluable drug, but I must pass on. Other drugs which are also injurous to eyesight are chloral, opium and the bromides.

Cosmetics which are placed in the eye to heighten its lustre should be avoided, as they are always dangerous; eye balms of all kinds should be avoided, especially if the ingredients are rich in the proportions of lead.

The same observations are applicable to the dyeing of the hair and eyebrows.

There is a case on record where a diminution of vision has been traced to the wearing of an artificial wreath of flowers.

In ancient Greece amd Rome, the business of painting the skin was a work of art, and ladies of wealth and fashion kept female slaves for the express purpose, but their paints consisted for the most part of the less injurious materials procured from the vegetable or animal kingdoms.

Another source of failing vision may be traced to impeded circulation. The wearing of tight neckwear, such as collars which are too small or shirt bands or neckties tightly drawn should be avoided, this prevents the downward column of blood returning to the heart; the blood being retarded is dammed up in the capillary blood vessels, the heart driving against this volume of blood is sure to cause dilatation of them and certain diseases develop. We are almost sure to have fulness of the head or headache following. To say the least, the equilibrium of the circulation is destroyed.

The same rules hold good to constriction of other parts of the body.

A subject which is commanding some attention is, "Are type-writing machines injurious to vision?" The individuals who find the most trouble with their vision are those who are students at this new calling. Close attention and concentration of vision is necessary to produce accurate copy. After one becomes so thoroughly proficient in manipulating the keys that he acts automatically, much relief is given to the eyes, but until this is accomplished, a great many, especially young girls, suffer from eye strain.

I have given this matter considerable attention for a long time, and I am constantly consulted by individuals who earn a livelihood by working at such machines six to eight hours daily and in some cases longer, and I find that the arrangement of keys has much to do with those afflicted with ocular disorders, for they who wrote on machines having circular key-tips almost always had eye trouble.

Among the many patients who have consulted me, I quote from one who has been using various machines now on the market; his language is as follows:

"In considering the various type-writing machines now in use, and the effect they have on the eyesight of those using them, I will make use of but three; namely, the Remington, Caligraph and Hammond, as these are the leading machines and the ones most in use.

"The key-board of the Remington machine contains thirty-eight keys, circular in form, with the letters printed on white paper covered with glass. On account of their arrangement, shape, size and color, they are very confusing, having a tendency to run together.

"The Caligraph has this same fault in a much more aggravated form, from the fact of its having a larger number of keys, thus tending to add to the confusion or running tendency which a multiplicity of keys produces.

"The Hammond has its key-board arranged in the form of a semi-circle, each key being made of ebony wood and shaped somewhat like a piano key, with the letter cut on them and filled with white enamel. The thirty keys represent, collectively, ninety characters, having fewer keys and more characters than any other machine, and yet the keys are made of such material, color and shape that they do not tire the eyes in using them."

This patient has been using type-writing machines almost constantly for the past five years; during the first two years he used a machine with round finger tips or keys, and he always experienced a burning sensation in the eyes as if small particles of sand had lodged under the lids; the smaller blood vessels looked congested and these symptoms became so aggravated that he consulted my assistant (I being in Europe at the time), to see if something could be done to relieve him from his misery. He could not read at night after working through the day. Prior to using this machine he had had no eye trouble of any kind. My assistant, who made a careful examination, found that he had no visual defect. He exchanged his type-writing machine, and after three years' constant use he has had no further trouble with his eyes.

Another patient, who has had a somewhat similar experience, tells me that while she has never used the Ideal Hammond, the black keys of the Caligraph are less hurtful to her eyes than the white keys of other machines.

Before a writer becomes so proficient that he can perform his work automatically, his eye strain must be enormous. If any visual defect exists I prescribe the proper glasses, and if round finger tips or keys are used I advise a change to be made to machines having rectangular keys, which I find are the least hurtful to the eyes.

Another source of eye strain is produced by constant reading in railway carriages. I have often been impressed by the avidity of passengers seizing their morning paper and devouring column after column to and from their places of destination. On account of the oscillating movements of the car the paper is held inside the proper reading distance; this is done to get a larger image of the reading matter, but in doing so the muscles of accommodation as well as the converging muscles are kept on a severe strain.

These same men pass rapidly from station to their places of business, neither looking to the right nor left of them, but with thought intent and fixed gaze they still hold these muscles with a strong grip; all day at business the same, and a repetition of the morning's work upon the train homeward bound at night, and so for ten or twelve hours those patient eyes are forced to work, which keeps up the strain, and on account of the tension more blood is brought to the parts, which in a short time produces failing sight and chronic congestion of the eyelids and eyeballs.

We must not forget that a certain amount of recreation is not only conducive to good health, but is absolutely necessary to preserve the same. Men who are constantly employed either at reading, drawing, adding up columns of figures or near work of any kind, should take short intervals of eye rest, especially those working upon white or glazed paper, wood-engravers or etchers. Nothing gives such eyes greater relief than a green disc or square of sufficient size, suspended on a direct line of vision at or against a wall on which the eyes can rest; but best of all if that individual can look upon a green grass plot or green trees.

School-rooms, instead of having blank walls, would be a source of great comfort to the overtaxed eyes of children if they were decorated with pastoral scenes, or any picture representing long distances.

Since the above was written, I have had an interview with Mr. Paul Kavanagh, Chairman of Public School property of this city, and he tells me that this idea has in a measure been adopted in the F. M. Drexel School, Sixteenth and Moore Streets. The walls are not only decorated with maps, but also with pictures of animals inhabiting certain portions of the globe. For instance, the map of Africa showing the black race, also that it is the land of the elephant, etc.

These drawings or pictures not only make school-rooms attractive, but what is more important, give the eyes a rest, while these same pictures are another means in the development of the minds of the smaller children by object lessons.

One of the most prominent and popular professors* in the Boys' High School, who speaks with an experience of twenty-five years, tells me that he has found the old-fashioned school maps with their glazed surfaces not only injurious to vision, but on account of their highly reflective surfaces difficult to see from certain positions. This style of map should have been banished from school-rooms years ago.

Pictures in which great distances are shown are the best for sitting-rooms. The drop curtains in theatres should have scenes painted on them showing great perspective; it is a rest to the eyes after the concentrated effort made in trying to watch the facial expressions or eyes of an actor, to look upon such a picture. The success of Russell Smith's scenic paintings on drop curtains, was that he always gave great perspective to his drawings.

Several theatres in this city have drop curtains in which perspective is absent, and the result is that no relief is given the eyes after each act, and people with the least visual defect always suffer from eye strain after spending an evening in such places of amusement.

Individuals who have to earn a livelihood with the pen should write on paper tinted green, blue or yellow. French authors use green tinted paper and say that they are greatly relieved from eye strain by doing so.

It is essential to preserve good sight by such means as will not interfere with good health, and the first step in that direction is to have plenty of light and air; not the heated atmosphere of the average American business place or home. I am sure that this high temperature helps to ruin people's eyes more than we like to admit; too much light, especially if it be reflected, is particularly injurious; it produces an overstimulation to the retina.

From what I have gathered from clinical observation, I find that a lesser quantity of light is less injurious to an eye than an excessive bright light. For example, miners have less visual defect than machinists who work under electric lights.

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* Prof. E. J. Houston.

The eye is so delicately adjusted that if one were to heed its warnings very little injury would result to it, but unfortunately men and women alike seem to think that at all times and under all physical conditions can this little organ be kept at high pressure; they never think that general diseases or such as usually manifest themselves in other organs may develop special eye diseases.

After the last epidemic of "la grippe" I was particularly impressed with the large number of patients complaining of the loss of power of the converging muscles of the eye. Upon investigation, I found that while these patients were confined either to bed or home, they would read incessantly.

The result of this overtaxation was weakened eye muscles, while so long as they remained unsupported by prisms the patient suffered with pain over the eye region, headaches and other evidences of eye strain.

Individuals when suffering from any depressing disease should be guarded as to the length of time they read or perform near work, as they should be to physical exertion of any kind.

It is not my purpose to go into a discussion of the medical side of the many injuries the eye receives in an indirect way, but persons who have a predisposition to catarrhal ailments, a rheumatic or strumous diathesis, must carefully avoid all sudden changes of temperature or sudden exposure of any kind, as the eye not infrequently becomes the culminating point of disease. I have seen such people greatly frightened by the sudden appearance of flying specks before their eyes.

People prone to over-eating with little or no exercise frequently have this condition as well, which is known to the profession as "Muscæ Volitantes." They are not, as many people think, the forerunners of cataracts or blindness—in fact, so long as they remain minute specks they are harmless. One thing they point to, and that is, the eye should have rest and the body made to work; an inverse condition of affairs should be brought about to that usually existing; plenty of outdoor exercise and very little near work upon white paper.

The state of the mind has much to do with vision. Violent affections or great passion, long continued grief and care, cause a diminution of the eyesight. It is recorded that extreme terror has induced blindness; violent anger or rage lessens the acuity of vision to a marked degree. All this acts like so many corroding cares perpetually undermining the stock of good sight Nature has given us.

The Archbishop of Seville, who died at the age of 110, when asked the secret of his longevity and good eyesight, said, "By being old when I was young, I find myself young now I am old."

There is one form of visual defect to which I have called attention in my former lectures before this Institute, and that is color-blindness.

In this discourse I shall allude to it not as a congenital defect, but as an acquired condition brought about by abuses.

The early history of cases of color-blindness have been imperfectly recorded; one goes back to 1684, and her case is recorded by Dr. Dawbeny as one whose vision was excellent but unable to appreciate any other color than white or black, although she could often read for nearly a quarter of an hour in the greatest darkness. Another case which is recorded more in detail is described by Robert Boyle, who writes, on p. 599, vol. 3, whose philosophical works were published in 1725, as follows:

"Two things were particularly odd in this case (he speaks of a gentlewoman twenty years of age). First, she is often troubled with flashes of lightning that seem to issue out like flames about the external angle of her eye, and often make her start, put her into frights and give her melancholy thoughts.

"Secondly, what is more strange and singular, she can distinguish some colors as black and white, but not others, especially red and green. And when I produced her a bag of fine glossy red, with tufts of sky-colored silk (blue) she looked attentively upon it, but told me that, to her, it did not seem red, but of a dark or dirty color, and the (blue) tufts of silk, she said, seemed to be of a light color, which she compared to the silken stuff of the petticoat worn by the lady who brought her to me, and, indeed, the blues were very much alike.

"She further said, that the meadows did not appear green, but of an odd darkish color, and that when she had a mind to gather violets, though she kneeled in the place where they grew, she could not distinguish them by the color, from the grass about them, but only by their shape or touch. And the lady who was with her took thence occasion to tell me, that when she looks upon a Turkey carpet, she cannot distinguish the colors, unless of those parts which were white or black."

Medical records show that this subject remained undisturbed until Dalton described his own case in 1794, and he appears to have been in ignorance of Boyle's writings. After this period, it was called "Daltonism," and even to this day it is sometimes known by this same name.

In 1846, Prof. Wartmann's elaborate paper was translated and published in *Taylor's Scientific Memoirs*, but it was left to Dr. George Wilson, of Edinburgh, who, in 1853, contributed elaborate articles to the *Edinburgh Monthly Journal of Medical Sciences*, and in 1855 published the best book written in English on the subject. Since Wilson's day, many articles have appeared on this subject; among our own countrymen, Dr. B. Joy Jeffries, of Boston, takes the lead.

A continuation of the knowledge of colors is very important, when we know that engine drivers or men on ocean steamers have daily to peril human life, "on the indication of a colored flag or light."

Congenital color-blindness is easily detected, and color-blinds rarely apply for important positions in which color plays a *rôle* in the occupation. It is after men have secured a position and are consumers of tobacco or have passed through a severe illness, that they should again be made to undergo examinations, for tobacco, quinine and santonine enter largely into the class of drugs which might produce such a defect.

Prof. John Speiller recently read a paper on the effect of santonine produced upon his color sense, which from a scientific point of view is interesting. I would, therefore, repeat, that all men such as engine drivers and seamen, should undergo an examination for color-blindness at least twice a year.

Dickens says somewhere that "nothing is sure in this world but death and the tax collector." I may add, that when the majority of people reach their forty-fifth year, they are sure of falling into the hands of the oculist and the optician.

One of the first concomitants of age, is acquired farsightedness or presbyopia. This necessitates wearing certain glasses for near work.

Whenever a man or woman about forty-five years of age finds himself or herself reading or threading a needle at arm's-length, their action tells that the little muscle governing the accommodation, is growing weak and needs assistance. By persisting in forcing this muscle to work, much injury is done to the eyes, but by having it corrected, many a frown would be saved to man and many a wrinkle to woman.

Not only is it important to get glasses, but of more importance still is it to see that you get the kind suitable for each eye. It is comparatively rare to find two eyes exactly alike, and the aid of an ophthalmic surgeon who is not only competent theoretically but practically should be sought.

Our city is noted for its skilled opticians, but it is also to the discredit of many of these same opticians that they will sell glasses to anyone who chooses to buy them. I do not for a moment entertain the thought that trained opticians cannot give glasses which will answer a given purpose; nay, I am sure that they can correct the simpler forms of presbyopia as well as any ophthalmic surgeon and optician.

Men whose knowledge is acquired by long experience are often much more useful than those having a theoretical knowledge only. When the optician finds, however, that the vision is not the same in each eye, or where astigmatism exists and the patient complains of symptoms now recognized as eye symptoms, then his province ends and the ophthalmic surgeon's work begins.

At one time the druggist could exercise the prerogatives of the physician; is it of lesser import that the optician should assume the prerogatives of an ophthalmic surgeon? If the law now prevents the one from prescribing drugs, the other should also be prevented from prescribing glasses, outside of a certain range of years, or certain physiological conditions.

As age increases, excessive reading, writing or work upon very small objects must not be persisted in, especially if the eyes grow tired. It must be remembered that the elasticity of the eyeball is lost and any persistent effort may produce hemorrhage in the retina, or such a strain as may lead to other serious troubles.

Old people should be careful not to read with a strong artificial light falling on a white glazed surface. It would be better for such people if our monthly magazines were printed on paper of a neutral tint.

I now come to speak of cataracts, the most common form of eye disease in elderly people; and being so common, it is astonishing in these enlightened days that the majority of people still believe the cataract to be a skin growing over the eyes.

In Vigon's *Chirurgerie*, published in 1571, I quote as interesting reading his description of a cataract: "Oftentymes, there descend from the head certayne grosse and flegmatyke humors covering the apple of the eye and there remaining, and engrossed and made thyck, which is named of the doctors, Cataract."

It was not until about 1700 or a few years later that the real seat of cataract was understood; until this time it was supposed by the medical men and oculists to be a growth or a skin as described above, and like so many sayings, was handed down from one generation to another and has lived to this day.

The removal of cataract can only be performed by an operation. The history of operations for the removal of cataracts date from the remotest antiquity. It was known in Egypt under the reign of Ptolomy-Soter; traces of it are found in the "most ancient traditions of Hindustan and the Chinese empire." Galen states that in his time there were oculists at Rome and Alexandria who exclusively practised this operation. In ancient and comparatively recent times the operation was performed by thrusting a needle into the eyeball a short distance behind the cornea, and turning the opaque lens downward or dislocating it completely; this removal of the cataract aided by a convex lens then gave the patient vision.

The operation followed by ophthalmic surgeons to-day is entirely different; an incision is made through the cornea with a delicate knife, and the cataract or opaque lens removed through this opening.

Many individuals with cataracts dread its removal, but with the aid of that powerful drug cocaine (which I do not believe the ancients knew anything about, and is possibly one of the few new things under the sun), and a skilled hand, successful restoration to vision is almost always anticipated.

Of all the special organs of sense the eye stands prominent among them all, like a barometer to indicate the physical condition within the body.

When patients are brought to us with red or inflamed eyelids and a history of a succession of sties, do we simply give eye salves? No! First, we seek for causes more remote and find them in defective vision.

When ulcers of the cornea exist, it shows that the blood must be impoverished and food is not assimilated.

When that white band around the outer edge of the cornea called the "Arcus Senilus" is visible, what does that indicate? Your physician will tell you that fatty degeneration of muscular tissues is taking place, and nothing must be done to produce over-action of the heart.

When the eyelids are puffy and seem to be filled with fluids, it tells the observing physician facts more potent than words.

The pupils of the eyes speak for changes going on in the brain or upper portion of the spinal cord, and when we examine the interior of the eye with the ophthalmoscope, what a new world is unfolded to the observing and keen ophthalmic surgeon! We are thus able to tell whether a patient is suffering from tumor of the brain or meningitis, Bright's disease or diabetes.

In this lecture I have tried to call attention to many evils which not only directly injure health, but the vision as well. It is a melancholy circumstance that so many young persons will deliberately try to undermine their good health, so that when they reach the age of fifty in years, they are at least seventy in aches and pains.

> "Hard toil can roughen form and face,
> And want can quench the eyes' bright grace.
> Nor does old age a wrinkle trace
> More deeply than despair."
>
> —*Marmion.*

In conclusion, I venture to give you a few more hints on the care of your eyesight:

(1) Avoid sudden changes from dark to brilliant light.

(2) Avoid the use of stimulants and drugs which affect the nervous system.

(3) Avoid reading when lying down or when mentally and physically exhausted.

(4) When the eyes feel tired, rest them by looking at objects at a long distance.

(5) Pay special attention to the hygiene of the body, for that which tends to promote the general health acts beneficially upon the eye.

(6) Up to forty years of age bathe the eyes twice daily with cold water.

(7) Do not depend on your own judgment in selecting spectacles.

(8) Old persons should avoid reading much by artificial light, be guarded as to diet and avoid sitting up late at night.

(9) After fifty, bathe the eyes morning and evening with water so hot that you wonder how you stand it; follow this with cold water, that will make them glow with warmth.

(10) Do not give up in despair when you are informed that a cataract is developing; remember that in these days of advanced surgery it can be removed with little or no danger to vision.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, May 17, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1892.

Dr. Wm. H. Wahl, President, in the chair.

A paper on "An Improved Method of Determining Small Percentages of Gold and Silver in Base Metal," by Mr. Cabell Whitehead, of Washington, D. C., was read by Dr. D. K. Tuttle. It was followed by an interesting discussion.

The paper was referred for publication in the *Journal.*

Mr. F. Lynwood Garrison then gave a number of views of the recently conducted armor-plate tests at Indian Head proving ground. Mr. Garrison discussed the results of these tests from the metallurgical standpoint. The complete report of Mr. Garrison to the Institute will appear in the *Journal.*

Adjourned. WM. C. DAY, *Secretary.*

AN IMPROVED METHOD OF DETERMINING SMALL PERCENTAGES OF SILVER AND GOLD IN BASE METALS, MATTES, ETC.

BY CABELL WHITEHEAD,
Assayer to the Mint Bureau, Washington, D. C.

[*Read at the stated meeting held May 17, 1892.*]

Any one having frequent occasion to report the values of silver and gold in such material as crude copper, copper mattes or ores, metallic iron, zinc, etc., will appreciate the advantages of a method which affords accurate results with little expenditure of time. The large production of pure copper by electrolytic methods from silver- and gold-bearing copper ores, renders some such method very desirable in view of the various transfers of, (1), ores to the smelters; (2), mattes to the refiners; and last, the crude copper to the electrolytic refinery, each of which transfers carries a commercial charge of the bullion contents.

While the proposed method is available for a great variety of base products, it will perhaps best be illustrated by its use in determining the silver and gold contents in crude copper or the mattes resulting from bullion-bearing copper ores. The adaptability of the method to other base metals will readily suggest itself to the experienced assayer.

Given a crude copper or matte carrying from thirty ounces of silver and ·10 of an ounce of gold, upward, the usual method would be scorification. It is usual to take for assay from ·05 to ·1 assay ton to each scorifier, with which are used from forty to fifty grammes of test lead, one-half of which is mixed with the ore in the scorifier and the remainder used as a cover. The scorifier is now introduced into a hot muffle and the door closed until the lead is melted, when it is opened and about one gramme of borax glass placed on the lead. Oxidation begins at once and the lead and base metals are rapidly scorified off until the slag covers the metal, when the assay is poured into a mould. If the lead button still retains much copper, or is hard or brittle, it is again scorified, with the addition of more test lead if necessary. When the lead button is soft and of proper size, it is cupelled and the button weighed and parted. Several scorifications are sometimes necessary before the button is ready for the cupel.

The two objections to this method are, first, the loss of silver during scorification and cupellation, the latter due chiefly to the copper remaining in the lead which it is practically impossible to remove in the scorifier, and which takes silver into the cupel. These losses I found to amount to from 2·33 to 2·78 per cent. of the silver present in the copper. My experiments were made with pure copper and pure silver, the silver being added in the proportion of 100 ounces per ton of alloy.

The second objection is the small amount of bullion which can be operated upon, which necessitates the use of many scorifiers where small amounts of gold are to be estimated, which is usually the case.

To avoid the doubtful results of scorification processes, the following method has been adopted at the copper works of a firm having large interests at stake:

One assay ton of copper is dissolved in nitric acid, diluted and allowed twenty-four hours to settle. The solution is now filtered from the slight sediment containing the gold. A few drops of hydrochloric acid are added to the filtrate and the solution again allowed twenty-four hours for silver chloride to deposit, when it is filtered, washed and the two filters dried, combined, scorified with test lead and cupelled. The chief objections to this are, (1) the time required; (2) the small amount of precipitate obtained and the danger of loss in scorifying silver chloride; (3) the greater solubility of silver chloride as compared with the bromide.

While the method used at these works is an advance over previous practice, yet the time employed and the uncertainties indicated, leave much to be desired. The protracted time allowed for settling is necessitated by the exceedingly fine condition of the gold resulting from the solution of a metal carrying possibly from ·10 to 5 ounces of gold per ton of metal. It would pass through a filter unless allowed to aggregate by standing.

The larger quantity (say 100 ounces) of silver per ton will give but a slowly subsiding cloud (impossible to filter) when newly precipitated as chloride. The scorification of these combined precipitates, one of them being silver chloride, cannot give results quite satisfactory, despite the time involved, some forty-eight hours at least.

The method which I will now briefly describe was devised to meet just such cases, and is suitable for the bullion valuation of zinc, iron, nickel, etc., as well as the sulphides and arsenides of iron and copper. To illustrate the proposed method, which has been found effective and useful, the treatment is detailed for a crude metallic copper carrying both silver and gold. It will be understood that sodium bromide is chosen as a precipitant because of the greater insolubility of silver bromide over the chloride, and also that the soluble lead salt is added in order that the heavy precipitate of lead bromide may envelop and promptly carry down the silver bromide cloud. which otherwise would require long waiting for its subsidence, as well as to furnish the lead necessary for cupellation.

Weigh out from one to four a. t., depending upon its richness, place it in a beaker of 500 cc. capacity and add gradually enough nitric acid to dissolve it completely. heat until red fumes cease to come off, dilute with water and add fifty grammes of lead acetate, stir, and when dissolved, add one cc. dilute sulphuric acid and allow the lead sulphate to settle. Filter into a 1,000 cc. flask and fill to the mark with distilled water.

The filter contains the gold which has been collected and carried down by the sulphate of lead. The filter paper and precipitate are dried, the paper burned and the ash and lead sulphate scorified with test lead. The button is cupelled and the gold, with any trace of silver it may contain, is weighed. Add silver and part the gold in the usual way. Note the amount, if any, of silver found and include the proper proportion of the amount with that found in the solutions as about to be described.

In order that there may be a control assay, the solution is divided into two equal parts, to each of which a saturated solution of sodium bromide is added with constant stirring as long as a precipitate is produced. The precipitates settle quickly and filter and wash well. Cold water only should be used, and the washing be continued until the washings are free from copper. Any bromide of lead dissolved during the washing, may be neglected, as I have never found it to contain more than a trace of silver, even when assaying ores carrying many thousand ounces.

The precipitate when dry can be brushed from the paper without difficulty, and thus the trouble of burning the filter is avoided. The bromides are now mixed with three times their weight of carbonate of soda and a small amount of flour or other reducing agent, placed in a small crucible, covered with borax glass and melted down in the muffle. The button should weigh about two grammes and be free from copper and other injurious impurities. This button is cupelled at a low temperature, so that the cupel "feathers" nicely. The time required is from three to five minutes. Duplicate assays usually agree within two-tenths of an ounce per ton.

The following examples are from copper bullion:

		Oz.	*Oz.*		*Oz.*
No. 1,	silver	61·30	61·20	gold	·10
No. 2,	"	63·45	63·30	"	·17

Had the gold button contained silver, one-half of its silver contents would have been added to the silver recovered from the solutions, since the gold is estimated on the whole weight, while two determinations of silver are made on the same weight.

The following is an example from a silver-bearing cast iron from the U. S. Mint at Philadelphia. It was dissolved in nitric acid, diluted and precipitated with lead and sodium bromide. After washing, the bromides were dried and brushed from the filter. No. 1 was mixed with ten grammes of litharge, a little flour, the usual amount of soda and covered with borax. Melted down and cupelled, the button gave 30·80 ounces per ton. No. 2 was mixed with test lead and borax and scorified. It gave 29·90 ounces per ton, ·90 of an ounce less than No. 1. However, this would be considered a very close agreement by the old method.

The following is an ore from Colorado, very base and with a gangue of sulphate of barium. It proved very unsatisfactory to assay by scorification, duplicates not agreeing at all. The ore was treated with nitric acid and filtered, the residue being assayed separately.

The following are my results:

	No. 1. Oz.	*No. 2. Oz.*
Residues,	32·50	35·95
Solutions,	454·90	453·30
As a total,	487·40	489·25
Difference of	1·80	

Gold was not separated in the residues. The highest assay gotten by scorification was about 467 ounces, which shows twenty ounces in favor of the new method, with a reasonably close agreement in different assays.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, May 3, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 3, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, thirty members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, which were approved and ordered paid.

One nomination to membership was referred to the Committee on Admissions.

The proposed amendment to the by-laws substituting the word *fourth* for *first*, in Article II, Section 1, so that it reads: "The stated meetings of the Section shall be held on the fourth Tuesday of each month, at 8 P.M., except during the months of July and August," was voted upon and adopted.

This by-law was then temporarily suspended upon motion that the next regular meeting shall be held Tuesday, May 31, 1892.

Mr. Paul A. M. Winand read a paper on "Some Points Regarding Multiphase Current," illustrated by black-board sketches and ingenious working models. To be continued at next meeting, and referred for publication. In discussion thereon, Mr. Carl Hering stated that he thought the term *multiphase* usually applied to currents of two or three phases, and *polyphase* to those of more than three. He and Mr. Wm. S. Aldrich described other diagrammatic methods of representing the variations in alternating currents.

Mr. Carl Hering read a paper on "Ampère-Centimetre: A Measure of Electro-magnetism." It elicited considerable discussion, and was referred for publication.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

CONSTANT SHUNT METHOD FOR THE MEASUREMENT OF LARGE CONTINUOUS CURRENTS.

BY CLAYTON W. PIKE.

[*Read at the stated meeting of the Section, held March 1, 1892.*]

The constant, Vienna or Munich, shunt method, as it is variously termed, is something which is by no means novel and is, indeed, well known to some of the section, having been used by them at the Electric Exhibition of the Institute, in 1884. But I believe that the method is not so well known, or at least not so much in use as it should be, and I hope, by calling attention to some of its advantages and by pointing out and showing how to avoid certain errors incident to it, one or two of which are not generally known, to do something toward bringing it into more general use.

For the measurement of continuous currents we have the various forms of ammeter, the Siemens dynamometer, the Thomson platform galvanometers, and the Thomson balances, the tangent sine and cosine galvanometers. With the objections to the ammeters all are doubtless familiar. They are inaccuracy of graduated scale, errors due to residual magnetism or to loss of permanent magnetism, and lack of wide range. The Thomson platform galvanometer does not measure large currents without the use of the permanent magnet which is objectionable if considerable accuracy is desired, and it requires a knowledge of the horizontal component of the earth's magnetism H. The Thomson balance is an instrument of much greater value than the above, being independent of H, having greater range and greater precision, but being even more costly.

The tangent galvanometer requires the value of H, and has only a limited range, which the sine and cosine, though better in this last respect, are tedious to use on account of time required in setting the coils.

The great advantage of the shunt method over all these is that, by the aid of fairly simple and cheap apparatus, currents varying from one to 1,000 ampères or more may be measured with quickness and a very great degree of accuracy over the whole range.

The shunt method is really a comparison method, and depends upon Ohm's law that the potential difference between two ends of a resistance is proportional to the current flowing through the resistance.

Let $A\ B$ be a conductor whose temperature is kept constant, its resistance will therefore be constant, but need not be known. Pass the current C, which we desire to measure through $A\ B$, there will then be a potential difference $P\ D$ between A and B.

Let G be a mirror galvanometer with telescope and scale, then the deflection d is proportional to the current through it, which is proportional to $P\ D$, as long as resistance of galvanometer and leads is constant, $d_1 \alpha P D_1$ or $d_1 \alpha C_1$.

Pass any other current C_2 through $A\ B$ then $d_2 \alpha C_2$ and

$$C_1 = \frac{d_1 C_2}{d_2}$$

If the resistance of the galvanometer and leads be not constant, the algebraical result is less simple and, moreover if the deflections become very large, they are not strictly proportional to the current through the galvanometer which we will call $C g$. Hence the comparison of large with small currents will be somewhat inaccurate. This leads us to a little different method. Place a resistance box R in the galvanometer circuit. Pass current C_1 through $A\ B$, causing a potential difference $P\ D_1$, and sending through G a current

$$C_1 g = \frac{P D_1}{R_1 + g}$$

where g is the galvanometer resistance.

Then

$$d_1 \alpha C_1 g \alpha \frac{P D_1}{R_1 + g}$$

or

$$C_1 \alpha d_1 (R_1 + g)$$

in the same way

$$C_2 \alpha d_2 (R_2 + g)$$

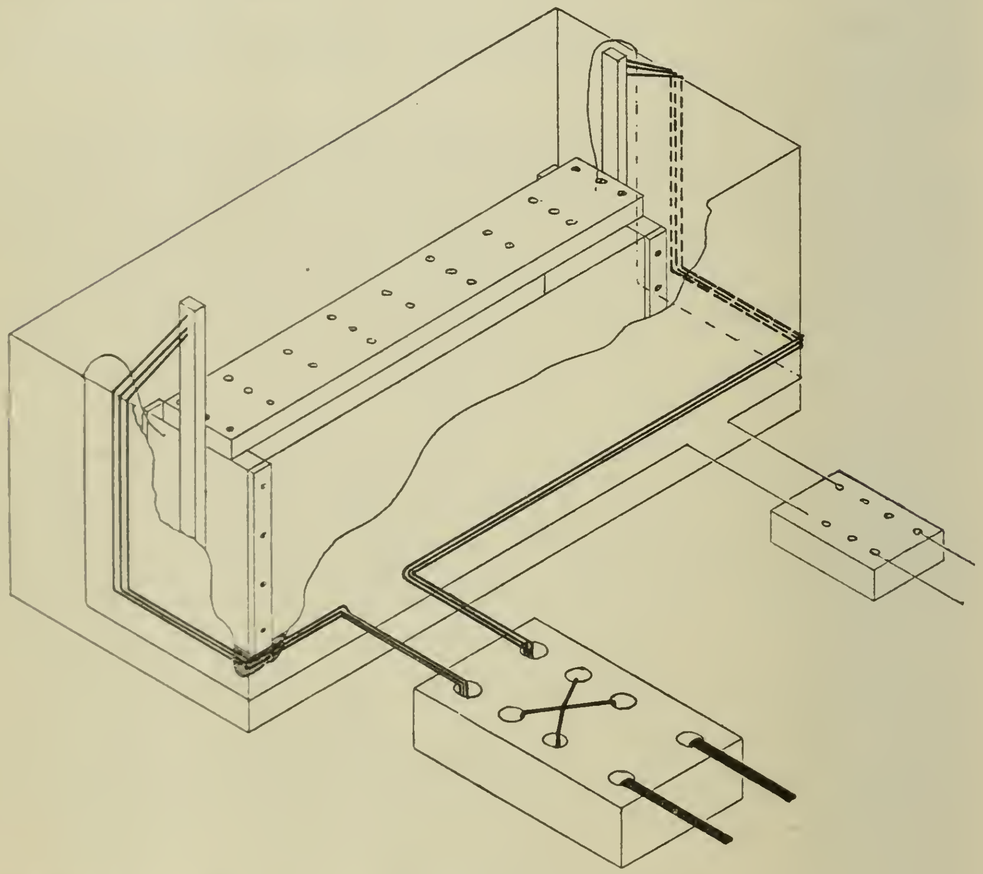
then

$$\frac{C_1}{C_2} = \frac{d_1 (R_1 + g)}{d_2 (R_2 + g)}$$

or

$$C_1 = \frac{d_1 (R_1 + g)}{d_2 (R_2 + g)} C_2$$

Now, if when C_2 were flowing we had accurately measured



it by a tangent galvanometer or by the electrolytic cell, the quantity

$$\frac{C_2}{d_2 (R_2 + g)}$$

would be known. Call it K the constant of the shunt. Then we have the general formula for the shunt that the current whose value we desire is equal to

$$d (R_1 + g) K$$

Now, by using the resistance box, and by adjusting it to give about the same deflections on the galvanometer in different measurements we have secured two important advantages.

(1) We have done away with the error of assuming that the currents through the galvanometer was strictly proportional to its deflections.

(2) The resistances R being large in value with reference to galvanometer and leads, and being of platinoid or some metal with very low temperature coëfficient, any change in temperature of galvanometer and leads will produce little effect on the result.

Like all other methods this one is liable to certain errors, some of which I will mention and briefly suggest their remedies. The way in which they affect the result will also be stated.

(1) *Reading of Deflection.*—Suppose you could read to within ·01 cm. on the scale. If the deflection were 10 cm. the error would be

$$\frac{\cdot 01}{10} = 1 \text{ part in } 1{,}000.$$

The error is evidently diminished as we increase the deflection.

(2) *Error Due to Temperature Change of Galvanometer and Leads.*—If these are of copper their resistance would change four-tenths per cent. per degree Centigrade. This correction could be applied, but if the resistance in R is large with respect to g, this correction will be negligible; (2°) then conflicts with (1°), and we must compromise. Suppose $R_1 = 20$ $g = 2$, and temperature rise = 10° C. then the true value of

$$R_1 + g = 20 + 2 + 2 \times \frac{4}{100} \times 10 = 22\cdot 08$$

and the error in neglecting the

$$\cdot 08 = \frac{\cdot 08}{22} = 1 \text{ in } 275$$

(3) *Error Due to Temperature Change of Box.*—This is ·02 per cent. per degree Centigrade for platinoid coils, and may be

corrected for, or neglected, according to the desired precision of our results.

(4) *Error Due to Determining Constant K.*—The constant is best determined in most cases by electrolytic cells, say three in series. If one has a tangent galvanometer of proper range, 1-5 ampères, and knows H to the desired accuracy this may be used. A Thomson deci-ampère balance would be very convenient for subsequent determinations of the constant, if its readings were known to be correct within the desired degree of accuracy. An error of ·1 per cent in K causes an equal error in the subsequent measurements.

(5) *Error Due to a Rise in Temperature of the Shunt.*—This may be due to two causes: a rise in the temperature of the room, or the heating effect of the current. Both may be obviated by placing the shunt in liquid artificially cooled by cold water coils, and keeping constant the reading of a thermometer placed in the liquid close to the shunt.

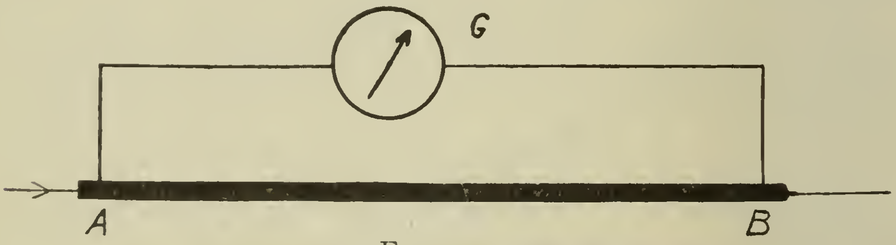


FIG. 1.

Suppose the rise in temperature were 5° C. If the shunt were of German silver the change in its resistance would be ·04 per cent. × 5 = ·2 per cent. or two parts in 1,000, and the results of the measurement would be in error by this amount. If of platinoid, the error would be but half as much.

(6) *Error Due to Change of Value of H.*—This would be possible if the galvanometer had the earth's field for a resting force. If great accuracy be desired, obtain the value of the constant frequently, and see if it changes. As I have before said a Thomson balance would be most desirable for this, and many laboratories can afford one Thomson balance. Also if we had a galvanometer whose damping could be removed, we could determine whether H had changed by its time of vibration. The sources of

error so far mentioned are well understood and looked out for, but the following are, I believe, not so well known. At least the amount of the effect is not so generally appreciated, and they have, so far as I know, received exhaustive study only at the hands of Mr. W. L. Puffer, of the Massachusetts Institute of Technology. His results are to be found in the *Proceedings of the American Academy of Arts and Sciences*, January, 1888.

(7) *Error Due to Thermo-electric Effects.*—We are obliged to make the resistance of our shunt very low to prevent undue heating, hence the potential differences set up at its terminals are very low. In this case any thermal E. M. F.'s, which might be caused by differences of temperature at the junctions of the different metals, would be liable to affect the readings of the galvanometer. This trouble may be obviated by so making the shunt as to put the junctions under the surface of liquid whose temperature is maintained constant and may be detected by running the galvanometer leads to a mercury cup commutator and testing with reversals.

(8) *Error Due to Electro-chemical Action.*—The shunt is placed in liquid and under the action of the potential differences set up at its terminals there is electrolytic decomposition, (if the liquid be one which can be decomposed as water). This will cause the end having the higher potential to be darkened, owing to oxidization of the German silver by the oxygen set free, while the other end will become whiter or cleaner in appearance, owing to the reduction of the film of oxide on its surface by electrolytic hydrogen. These actions will evidently set up E. M. F.'s, and if the shunt resistance is very low, will cause considerable error in the result. This source of error could be avoided by placing the shunt in some liquid incapable of decomposition with low E. M. F.'s. Chemically pure water would do, but for the trouble of obtaining and keeping it so. Petroleum oils would act slightly on the bare piece of metal composing the shunt, thus producing a battery effect. We must either immerse the bar in some liquid incapable of acting on it or cover the shunt very carefully with some substance not acted upon

by the liquid in which it is placed. Everything considered it seems to me that very carefully covering the shunt with several coats of shellac and afterwards with copal varnish, and immersing it in distilled water would be the most satisfactory method.

Design and Construction of Apparatus.—Suppose we desire to measure currents of from one to 1,000 ampères. This would require a set of five tangent galvanometers of different sizes, the three largest of which would be impracticable. (The diameter of the largest would be about seventy-five feet.) With the sine or cosine galvanometers or Siemens dynamometer we could do better in this respect, but they are still out of the question.

With the Thomson platform or balance we should need three different instruments, which are exceedingly costly.

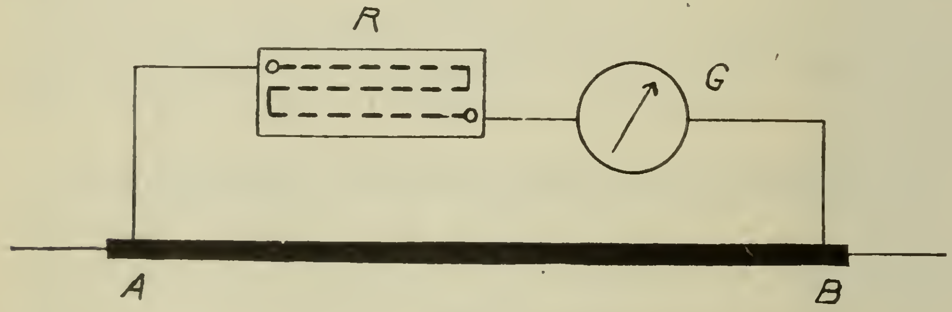


FIG. 2.

Moreover, none of these could be used near dynamos and this means that we must lead the whole of the current we wish to measure perhaps a considerable distance, thus entailing expense for wire and perhaps leakage.

Suppose we make one shunt of resistance ·001 ω. If of German silver 9 inches wide, $\frac{1}{100}$ inch thick, two strips 24 inches long joined in parallel will be nearly the required dimensions. The object of making them so thin is to offer large surface to the water so that they may quickly dissipate the heat produced by the current. The rate of production of heat with the maximum current 1,000, ampères, will be $\cdot 24\ C_2 R = \cdot 24 \times 1{,}000^2 \times \cdot 001 = 240$ calories or enough per second to heat 240 grammes of water 1° C. if none of the heat be dissipated. We must now provide a containing vessel large enough to hold so much water that it will not be unduly raised in temperature, and large enough to admit of placing in it coils of pipe which shall carry cooling water if this be found necessary with the larger currents.

The two German-silver strips should be joined thus by massive cast copper blocks, to which they are carefully soldered. To make the junction doubly secure, thin strips of copper 9 x 1 x ¼ inch are screwed and soldered on over the German silver, as shown. The vertical projecting copper bars *D* and *F* are for connecting the shunt into the circuit where we wish to measure the current.

The arrangement so far described would collapse, owing to the thinness of the German silver. So it is necessary to hold the copper blocks apart at the top and bottom by some arrangement which shall be insulated from the shunt. This can be done by screwing on to both top and bottom of the copper blocks, a piece of board 24 x 4 x 1 inch, as shown in drawing. The board on top should be pierced with a large number of holes, as shown, in order to facilitate the circulation of water. The ends of the boards touching the blocks should be soaked thoroughly in melted paraffin and coated with shellac. The screw holes in the blocks should be filled with paraffin, the screw heads countersunk in the wood, as shown, and melted paraffin poured over them. The whole arrangement should then be coated with shellac and copal varnish *thoroughly*.

The containing vessel may be of wood, paper or galvanized iron, about 32 x 14 x 13 inches. Such a vessel will contain, besides the shunt, about 85,000 grammes of water. Now, the number of heat units, small calories, developed in one second by 1,000 ampères flowing through ·001 ω is in one second as before stated, such as would heat 240 grammes of water 1° C. Hence it would take to heat 85,000 grammes 1°, a time $\frac{85000}{240}$ seconds, or about six minutes, if there were no radiation. But it is probable that this heat produced will not be instantly communicated to the entire mass of water, hence, for the large current measurements it will be advisable to lead coils carrying cold water close to the German-silver strips, both inside and outside, if we desire great accuracy in our measurements.

Galvanometer.—Any form of sensitive reflecting galvanometer which is dead heat and wound with coils of low resistance may be used. If the instrument has the earth's field alone for a restoring force, as is generally the case, (neglecting torsion), it would be convenient to have the damping copper mass easily removable. The following will illustrate the design:

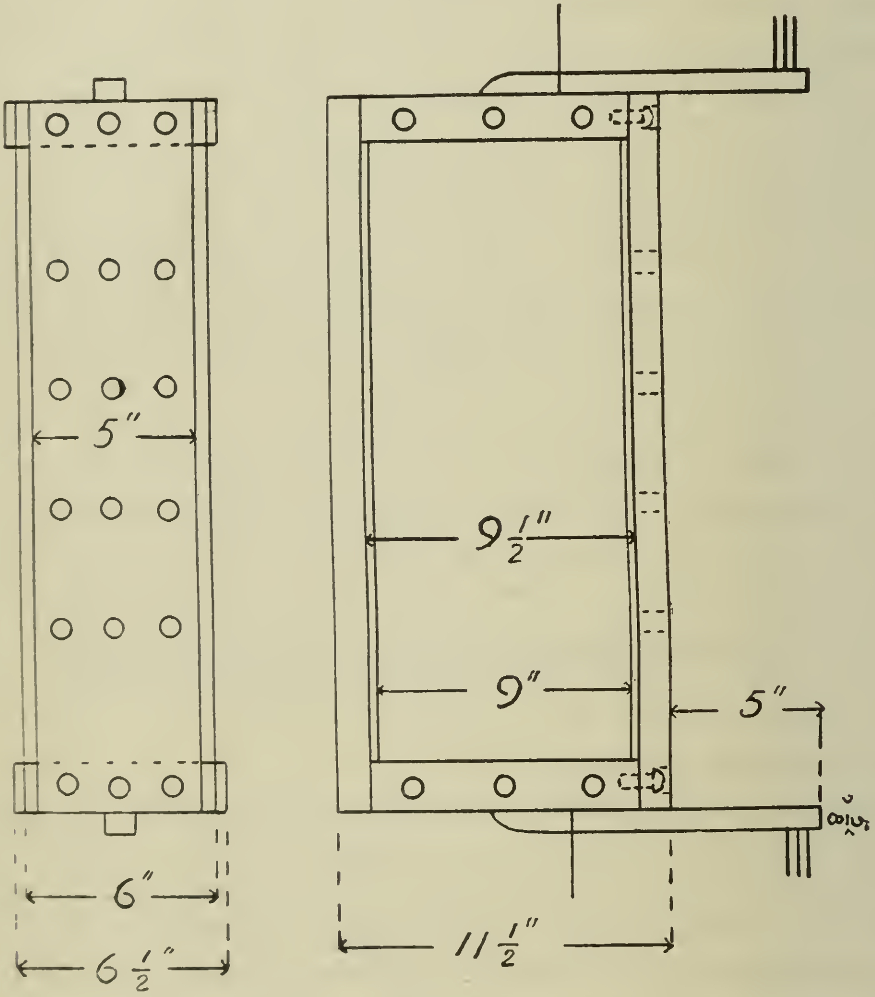


FIG. 3.

Suppose the scale of telescope is divided into millimetres, and we can read with an error of ·1 mm. by eye estimation, then with a deflection 10 cm. the error in reading would be $\frac{1}{1000}$ = 1 in 1,000. If our scale were distant from mirror of telescope by 1·5 metres, the deflection of the mirror for a reading 10 cm. would be about 2° for $\frac{10}{150} = tan.\ 2\,a = 2\ tan.$

α approximately. $tan.\ \alpha = \frac{10}{300} = {\cdot}033$ and α the deflection of mirror = 1° 54′.

When 1,000 ampères are flowing, the potential difference acting to send a current through the galvanometer is 100 × ·001 or one volt. Suppose we put in the galvanometer circuit 10,000 ohms, the maximum of an ordinary box, then the current through the galvanometer will be ·0001 ampères. With sufficient accuracy, we may apply the tangent galvanometer formula,

$$C = \frac{10\ H\ \gamma\ tan.\ \alpha}{2\ \pi\ n}$$

from which we have

$$n = \frac{10 H\ \gamma\ tan.\ \alpha}{2\ \pi\ C} = \frac{10 \times {\cdot}2 \times \gamma \times .033}{2 \times 3{\cdot}1416 \times {\cdot}0001}$$

Assume a mean radius $\gamma = 2{\cdot}5$ cm., then n the number of turns = 266 = 41·78 metres or about 136 feet of wire. If we take a copper wire whose diameter bare is ·036 inches the resistance will be about 1·1 α, and the wire will lie in a groove 1 × $\frac{5}{8}$ inch, whose mean radius is 2·5 cm., or about one inch.

When one ampère goes through the shunt the potential difference will be 1 × ·001 = 1 volt. Then to give about 10 cm. deflection we should insert such a resistance that the galvanometer current would be ·0001, and this resistance would be about nine ohms. Then should the temperature of the galvanometer coil rise 5° C., the resulting error would be but two parts in 1,000 from this cause alone.

A galvanometer of the D'Arsonval pattern might be used and would have the advantage of being independent of any changes in H, and of being very dead beat. It should be designed with as low resistance as is consistent with the condition that a current ·0001 ampères shall produce a deflection of 2°.

Two commutators are necessary. The larger receives the six coarse wire soldered into the copper lugs $D\ F$ of the shunt, shown in *Fig. 3*. These wires should be No. 0000 B. and S. three in parallel, and the commutator of the mercury cup variety, so arranged that the shunt can be entirely disconnected from the dynamo circuit.

Into each of the holes at *H* and *K*, *Fig. 3*, should be soldered, carefully, a No. 18 B. and S. copper wire thoroughly insulated, and the joint covered carefully with shellac and copal. These are led out to the small mercury commutator for the galvanometer circuit arranged like the other so that the galvanometer can be isolated from shunt and main circuit. Then any thermo electric or electro chemical effects can be detected and studied. For instance, disconnect galvanometer entirely from commutator and note reading. Connect it to commutator with shunt unconnected, and there should be, of course, no deflection even by reversing the commutator. Connect shunt (still with no current in it) to galvanometer commutator, and see if there is any deflection, reversing this time the connection from shunt to galvanometer. Finally, run current through shunt, and see whether changing the commutators produces any change in deflection, being sure that this current is maintained constant. Disconnect shunt from dynamo circuit, and see whether there is any appreciable deflection. The time occupied for these tests is very short, if the commutators are properly arranged, and if the tests show no appreciable thermo-electric or chemical effects, we may feel

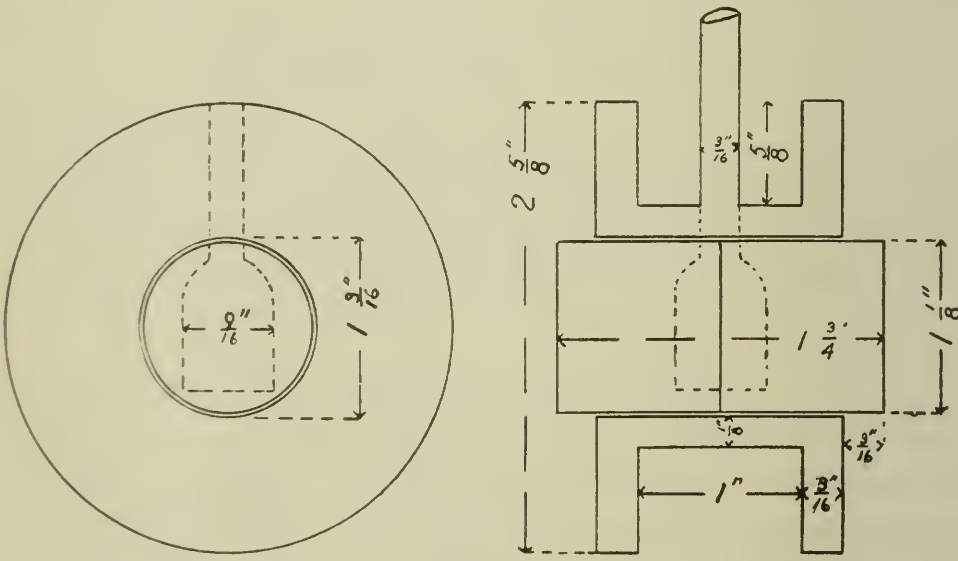


FIG. 4.

sure that our apparatus is satisfactory in this respect. Finally, provide a sensitive thermometer whose range is from about 60° F. to 80° F., or 15° C. to 27° C., and arrange so that it will be placed close to one of the German-silver strips of the shunt. Read when no current is flowing, and then when the maximum current flows. Then if these readings differ 5° C., or 9° F., the error would be two per cent., as previously stated. If greater accuracy be required send cold water through the coils, and read the thermometer, then by sending the water through fast enough, the heating effect of the current may be nullified to the desired extent.

The sketch below shows the general appearance of the completed shunt, together with the commutators.

Recent researches of Prof. Ayrton on the D'Arsonval galvanometer indicate that such a type wound with platinoid with phosphor-bronze strip suspensions would be most desirable, and, therefore, the following arrangement commends itself, more especially where the field around the galvanometer is subject to fluctuations. Use for the shunt bar a sheet of platinoid, to which the wires carrying the main current should be soldered. Preferably there should be several such wires soldered on the end edge of the sheet and distributed at equal distances along the edge so as to secure uniform distribution of current in the strip. *Inside* at the points *A* and *B* the leads (of platinoid) to the galvanometer commutator should be fastened. If then a D'Arsonval, made as above and having its telescope and scale rigidly attached to itself, be provided, it may be used where the other arrangement would be out of the question, namely, near the dynamo room. Moreover, by making everything of platinoid, we have done away with temperature correc-

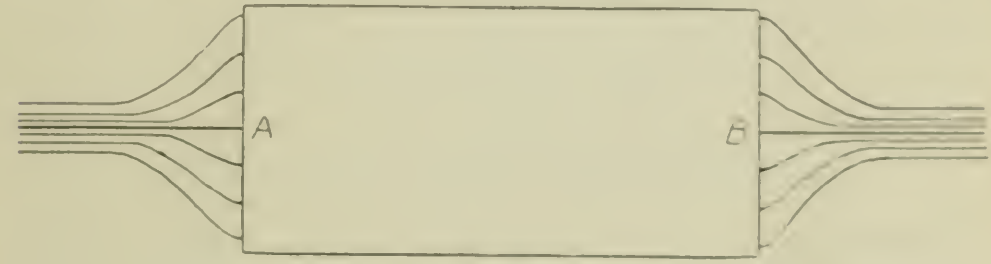


FIG. 5.

tions, provided the platinum strip be of such dimensions that the maximum current doesn't heat it appreciably. The strip then may be kept in air, the only danger being a greater liability to thermo-electric effects due to differences in temperature at the junctions, and this can be tested by commutation.

Using the D'Arsonval, we can get a greater deflection for a given potential difference at its terminals, therefore, the resistance of the strip may be made lower and less energy be used up in the method of measurement, and in some cases this is an important advantage. On the other hand, since we measure with smaller potential differences, any thermo-electric effects will produce a greater error in our results.

CEREBRAL RADIATION.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section, March 1, 1892.*]

Gentlemen: I have thought it possible that it might interest you to consider some rather wild speculations in which I have indulged for a number of years past, but which I have heretofore refrained from publishing. In these speculations, to which I was first led by a suggestion from a friend, I have endeavored to correlate, to some extent, the phenomena of thought with grosser physical phenomena. Although the suggestions I have to offer as a basis for a hypothesis of the mechanism of cerebration, are confessedly incomplete, and, perhaps improbable, yet I have concluded to place them on record as of possible interest to the scientific world.

I am, of course, aware of the fact that the psychical operations of the brain are by no means understood. It is generally believed, however, that the seat of psychical activity is the cerebrum. The manner in which the brain acts to produce, record, and reproduce thought is unknown, and will probably remain unknown.

On the single assumption, however, that cerebration or thought, whatever may be its exact mechanism, is accompanied by molecular or atomic vibrations of the gray or other matter of that part of the brain called the cerebrum, I would propose the following hypothesis to account for telepathy, mesmerism, thought transference, hypnotism and other cognate phenomena.

Postulating the existence of the universal or luminiferous ether, which is now generally accepted in scientific circles, and bearing in mind the fact that this ether passes through even the densest matter, as easily as water through a sieve, it follows that the brain atoms or molecules that are here assumed as the cause of cerebration, are completely surrounded by the ether. Now, since the ether is a highly elastic, easily movable medium, it would follow that thought or cerebration, if attended by vibrations, must necessarily develop in the ether wave-motions, which have the brain atoms or molecules for their centres. In other words, the act of thought or cerebration necessitates an expenditure of energy, because it necessitates the setting in motion of these assumed atomic or molecular brain particles.

The exact nature of the motions that are assumed to attend an active condition of the brain must necessarily remain unknown as long as we are ignorant of the exact nature of the mechanism that is moved. But, if an active brain evolves thought because something is set in motion, it, of course, follows that a brain absolutely free from producing thought must be at rest so far as that kind of motion is concerned. An absolute freedom from thought in a healthy brain is most probably a condition that seldom exists; relative rest, however, must be quite common.

That the brain cells, of the gray or other matter involved in the production of thought, can be caused to assume certain groupings or relations towards one another would appear to follow from the ease with which that curious function of the brain called memory, permits it to readily recall past peculiarities in the to-and-fro motions. By continually repeating certain trains of thought, as in study or repeated observations, the peculiar motions required to produce such thought are probably given a set or tendency to form more or less permanent groupings. When, therefore, the brain is moved or played upon, so to speak, these motions recur and certain memories are awakened.

How may these motions be produced? The answer would certainly appear to be both from within and without. It is, perhaps, possible that the flow of blood to an active brain, which as is well known attends all active cerebration, is not only for the purpose of nourishing and rebuilding the organ, but also for affording the purely mechanical force, that needs but to touch this marvellously attuned organ to awaken the thoughts already impressed thereon, or to sit in judgment on new combinations never before presented to it.

I will suggest an explanation later on as to how these impressions may possibly be excited from without.

Whatever be the origin of these vibrations, or, however, excited, energy is required to be expended in producing them, and as the brain-worker will readily acknowledge, the expenditure of such energy often calls for an enormous expenditure of nervous force.

Cerebral energy, or energy thus expended in producing thought, is dissipated by imparting wave motions to the surrounding ether, and such waves are sent out in all directions from the brain, possibly in greater amount, or of greater amplitude from some of the brain openings, as, for example, those of the eyes.

Although there are no absolute proofs of the existence of the molecular or atomic vibrations of the brain particles which I have assumed, such a movement, however, is far from being improbable, and, indeed, some facts known to the medical profession are far from being at variance with such an assumption. A certain amount of pressure on the brain arising from the pressure of the blood is necessary for its proper action. If this pressure increases beyond a certain value, as, for example, in cases of fractures of the skull, where a portion of the bone is depressed by the fracture, thereby producing a compression on the brain material, all thought or cerebration instantly ceases; but when this pressure is relieved, by the act of trephining, cerebration not only begins, but curiously enough, generally goes on from the point where the patient left off, when the injury occurred.

Let us assume, then, that cerebral radiations or waves are given off from every sentient or active brain, and that these waves pass into the space around the brain something like the waves that are imparted to the air around a sounding tuning-fork.

The cerebral radiations are not so gross as those of sound. Their wave-lengths are almost certainly much shorter. They are imparted to the universal ether.

If such waves, which I would call thought-waves or cerebral-waves, be present in ether that fills all space, it will be interesting to inquire what phenomena they might be expected to produce.

It being assumed that these vibrations take place in the ether itself, there need be no doubt or speculation as to the general nature of the waves themselves. They would presumably partake either of the nature of transverse or torsional vibrations.

The commonest character of the vibrations which occur in the universal ether are the vibrations which are now generally recognized as transmitting the phenomena of heat, light, electric or magnetic radiations; viz., of transverse or torsional vibrations.

An active brain may, therefore, be regarded as moulding the ether around it into thought-waves, that are spreading outwards from it in all directions. In this respect, it is not unlike a conductor through which an oscillatory discharge is passing, producing those waves which Hertz has so beautifully demonstrated as resembling the vibrations that produce light.

Assume, then, that the cerebral radiations partake of the nature of thermal, luminous, electric or magnetic radiations, and the following explanation of telepathy, or thought transference, is, to say the least, not improbable.

I would explain the possibility of the transference of specific cerebral vibrations from an active brain, to a passive or receptive brain, by the simple action of what is known in science as sympathetic vibrations.

Take the case, for example, of a vibrating tuning-fork, that is sending off its waves across the space which separates it from a second tuning-fork, not as yet in motion, but tuned so as to be able to vibrate in exact unison with it. As is well known, the exact correspondence between the period of the active, or the transmitting-fork, and the passive- or the receptive-fork, is such that the vibrations of one fork are gradually taken up by the other fork, so that the energy of the motion of the one is transferred or carried across the space existing between them, by means of pulses or waves, set up in the air which surround them.

As is well known, such sympathetically excited vibrations can be produced in a fork situated at a considerable distance from the exciting-fork.

Or, similarly, take the case of the sympathetic vibrations excited by waves of light. Solar energy is radiated or transferred across the space existing between the sun and the earth by waves or oscillations in the luminiferous ether. These waves, falling on the delicate structure of a leaf, suffer a species of selective absorption, certain wave-lengths being absorbed and others thrown off. The absorbed waves excite or produce sympathetic vibrations in the molecules of carbon dioxide present in the leaf, and cause the atoms of carbon and oxygen in such molecules to move towards and from one another in inter-atomic vibrations, which increase in amplitude or violence until their chemical affinity or atomic attraction is overcome and dissociation occurs. The oxygen is then thrown from the leaf into the air, and the carbon is retained in the structure of the plant.

Or, take the still more interesting case of what Hertz calls electric resonance. As already mentioned, it is now generally recognized by electricians that a conductor, which is the seat of an oscillatory electric discharge, is sending into the space around it electric waves or oscillations which travel with the velocity of light, and which are in fact of exactly the same nature as light itself. If these electric waves meet a circuit so tuned as regards the period of oscillation of the circuit in which they originally occurred, as to be in consonance with them, electric oscillations will be set up in this circuit, of exactly the same nature as those exciting it.

In view of these facts it does not seem improbable to me, that a brain engaged in intense thought should act as a centre of cerebral radiations, nor that these radiations proceeding outwards in all directions from such brain should affect other brains on which they fall, provided, of course, that such brains are tuned to vibrate in unison with them. In such cases the absorption of energy by the recipient brain may be either a species of selective absorption, in which its train of thought is only modified, or it may be absolute, in which case the recipient brain has excited in it an exact reproduction of the thoughts of the exciting brain.

Such a hypothesis is far from improbable; on the contrary, it would appear to be supported by a variety of curious circumstances, which have only wanted some general hypothesis to properly correlate them.

If such a hypothesis be true, then these cerebreal vibrations or radiations must travel through space with exactly the velocity of light. This is of course on the assumption that the vibrating or oscillating brain molecules or atoms set up vibrations similar to those of light. Of course, this equality between the velocity of cerebral wave propagation and that of light is true only for free ether. In the ether which fills the interatomic of intermolecular spaces of gross matter, or, as it is technically called, combined ether, the velocity of wave propagation varies according to the particular character of the matter with which it is associated. A retardation or decrease in the velocity of the assumed cerebral waves would doubtless be experienced while passing through the materials of the skull and head.

If thought travels along waves in the ether similar to waves of light, it would be able to travel along any path by which rays of lights cax pass. It can therefore travel along rays of light, *i. e.*, along paths in the ether through which rays of light are moving.

There is a well-known experiment in hypnotism, in which the patient, placed in a state of semi- or complete unconsciousness, has his brain called into a more or less active condition by the suggestions of the hypnotizer, which might seem to somewhat favor the hypothesis of cerebral radiation.

It might be interesting, in view of the above suggestions, to see whether a hypnotizer, placed in such a position as regards the hypnotized that flashes of light falling on his eyes shall afterwards fall on the eyes of the patient, to observe whether or not acts of suggestion are more readily perceived by the brain of the hypnotized along such rays of light than without the aid of such rays.

If the preceding speculations be regarded as wild, and that this is true I have already granted, what may not be said as to the following?

If thought radiations partake of the nature of ether-waves, then there should presumably exist in the thought radiations or waves, phenomena corresponding to the various phenomena of thermal, luminous, electric, or magnetic radiation; even the phenomena of reflection, refraction, and possibly even of dispersion of such waves, would appear to be a possibility. In this connection, it is of interest to imagine the analysis or separation of a complex wave of thought into its component or elementary waves, corresponding to the separation of a beam of light, by means of a prism.

In this connection, there would be a new significance in the phrases, "radiant with thought," or, "to concentrate one's thoughts on a subject."

If thought radiations or waves partake of the nature of light, then it would seem among the remote possibilities of science—to obtain, say by means of a lens—a photographic impression of such thought-waves on a suitably sensitized plate, somewhat after the manner of the ordinary photographic picture. Such a thought-record, suitably employed, might be able to awaken at any subsequent time in the brain of a person submitting himself to its influences, thoughts identical to those recorded.

Of course, I am aware of the improbability of such a record being obtained in the near future, and of the exceeding difficulties that would seem to stand in the way of ever obtaining it.

Until we know something more definite concerning the nature of these assumed cerebral vibrations and of their lengths, we must necessarily be seriously handicapped as how to best permanently fix them on a suitable record-surface, and how afterwards to cause such record-surface to interpret its peculiarities to the brain. I merely throw it out as a possibility of what science may have in store for those who come after us. I would suggest, in this connection, that 100 years ago it would probably have been regarded as quite impossible that the telephone or the phonograph could have been produced.

Such a thought-record, however, if obtained would not be an image of the thought itself, or of the particular groupings of the particles, whose to-and-fro movements attend or produce thought, any more than the tracings of the phonograph record form an image of the spoken words. They would merely represent the to-and-fro motions of the ether set in motion by the thought or cerebrations.

An eye looking at such an image would not be influenced thereby. If, however, ether waves similar to those recorded could be reproduced by causing light to pass through such photographic images of the to-and-fro motions of thought-waves, such waves might be caused to influence the brain and thereby awaken thoughts similar or identical to those recorded.

I have often amused myself with picturing a possible thought-recording machine, whereby the thoughts of an active brain might be recorded continuously and permanently on a moving sensitized film, the exposed surface of which was placed at the focus of a large lens placed in front of any one engaged in intense thought.

If, like the cylinder or plate of a phonograph or gramophone, such a record were afterward rotated at the same speed as that at which it received its impressions, under circumstances in which light passing through it is moulded into waves similar to those recorded on it, such waves when caused to act on a receptive brain, should, it would certainly seem, excite therein thoughts identical to those recorded as its record-surface.

Of course, it is needless for me to say that such a machine has never been actually constructed and is still as unsubstantial as are the speculations which I have offered you. Indeed, the probabilities against its being produced are so great that I have hesitated even to mention it.

Some experiments might be tried in a similar manner in thought transference, by holding large lenses in front of the eyes of a hypnotizer at such a distance as to converge the assumed cerebral radiations on the eyes of the hypnotized. These experiments might be tried either along with light, or independent of it.

I know that many points of the hypothesis which I have suggested are quite improbable, and that I may and probably will be misunderstood by some as putting forward facts rather than a bare hypothesis.

Probably one of the most serious objections to the hypothesis is to be found in the fact that the phenomena of telepathy and thought transference are not of more frequent occurrence. This I must frankly acknowledge to be a most serious objection. I would suggest, however, that the comparative infrequency of the phenomena may possibly be explained by the presence in the human body of a shield which protects the brain or the nerve centres from the effects of cerebral radiations. It is not impossible the sheathes of the nerves act as screens to prevent the reception by the brain of these thought radiations.

Prof. Tyndall, in his work on sound, alludes to the well-known fact that when sympathetic vibrations are being excited by a sounding tuning-fork in any body near it, that there is a greater rapidity of expenditure of energy of the fork's motion than when it was not exciting such waves. The analogue of this phenomena exists, perhaps, in the case of the assumed thought transference. Mental energy is presumably expended at a greater rate when it is exciting thought-waves in this manner, than when such are not being excited.

There has often been experienced by me as a teacher a feeling of great exhaustion in taking charge of or watching a room in which a number of bright students were undergoing an examination. It is possible that the cause of this exhaustion is the rapid dissipation of energy by the cerebral radiations being absorbed by the receptive brains of the examinees. I am informed by certain physicians, that a feeling of great exhaustion is experienced by them in the treatment of some cases.

If there be any truth in the hypothesis I have briefly outlined, there should be what I would term a kind of vital radiation going on and passing outwards from the body of a healthy person, which may not improbably excite by sympathetic vibrations in the bodies of weaker persons around them, vibrations of a normal or more healthy type than those present in the sick person.

If this be true, the old belief of the efficacy of the laying on of hands, or of magnetic healing, may find some foundation, in fact, apart from what is most probably the general explanation of such causes, viz., hysteria.

I have thrown out the above hypothesis of cerebral radiations with considerable doubt and hesitation as a suggestion only to those working in the field of telepathy or thought transference, in the hope that I may thereby call the attention of such investigators to some phenomena in this very obscure field of research.

DYNAMO AND MOTOR CALCULATION.

By C. H. Bedell.

[*Read at the stated meeting of the Electrical Section, April 5, 1892.*]

In the calculation of the different parts of a dynamo or motor, the work is of course divided into the calculation of the armature, and that of the field; but as the capacity and smooth operation depend principally upon the construction of the armature, it should be worked out first. This work is best divided into two parts; and since the dynamo is primarily a generator of E. M. F., the first consists of the calculation of those parts which affect the generation of the E. M. F., and the second in proportioning the parts that they will stand the currents which may be allowed to flow.

The part of the work which I wish now to consider, is that of the generation of the E. M. F.

For this, one must know to what extent the proposed field will saturate the armature core, since the E. M. F. is generated by the wires of the armature cutting the lines of force which the field causes to pass through the armature core.

One definition of a unit of E. M. F., is that E. M. F. generated by a conductor cutting one line of force once a second. Broadly the E. M. F. generated = lines of force cut × number of times they are cut per second. The E. M. F. is consequently proportional to the number of lines of force cut, and also the rate at which they are cut.

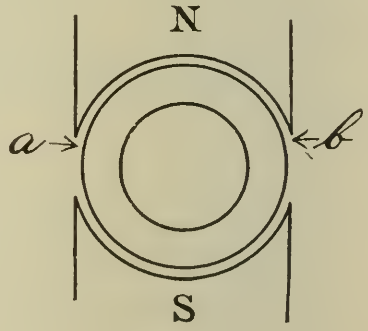
The rate at which the lines of force are cut is easily obtained, for the total number of conductors on the surface of the armature T, multiplied by the revolutions per second R, gives the number of conductors which cut the lines of force in a second, or the rate per second.

The number of lines of force cut is obtained by multiplying the number of square inches of iron in the cross-section of the armature core C, by the number of lines of force which is known will produce the desired degree of saturation L. Knowing the rate of cutting, and the number of lines of force, we have then the E. M. F. (in absolute units)

$$= T \times R \times C \times L,$$

or

$$\frac{E.\,M.\,F.}{10^8} = \frac{T \times R \times C \times L}{10^8} = \text{volts.}$$



This equation has only one factor about which there can be any uncertainty, which is the factor L; but as a very slight acquaintance with the form of dynamo to be constructed, or a careful calculation of the magnet circuit, will give the possible degree of saturation, there can be said to be very little uncertainty even in this factor.

The most satisfactory degree of saturation of the armature core, is with 90,000 to 100,000 lines of force per square inch of iron in the cross-section of the armature core, which can be obtained with the usual percentage of watts used in the field.

The annexed chart will greatly facilitate this calculation. It is of the same general plan as Mr. Carl Hering's wiring charts published in his *Wiring Computer*, and is used in the same manner. The interpolations for values between the diagonal lines are different in this chart, as the readings in the upper left-hand field should be along a horizontal line, and those in the upper right-hand, and in the lower left-hand field, should be along vertical lines.

It will be noticed that although the chart covers all the usual sizes of generators, yet calculations can be made with it far beyond its limits, as the different factors are so related to each other that where one is changed another can be changed porportionately, except in the case of lines of force per square inch. In the case of lines of force per square inch, values cannot be obtained higher than 100,000 lines per square inch with economy, on account of the iron being saturated at about that point.

If higher values of E. M. F. are desired than those given, the figures in the scale of E. M. F. can be doubled, provided any one of the others, except the lines of force per square inch, is doubled also.

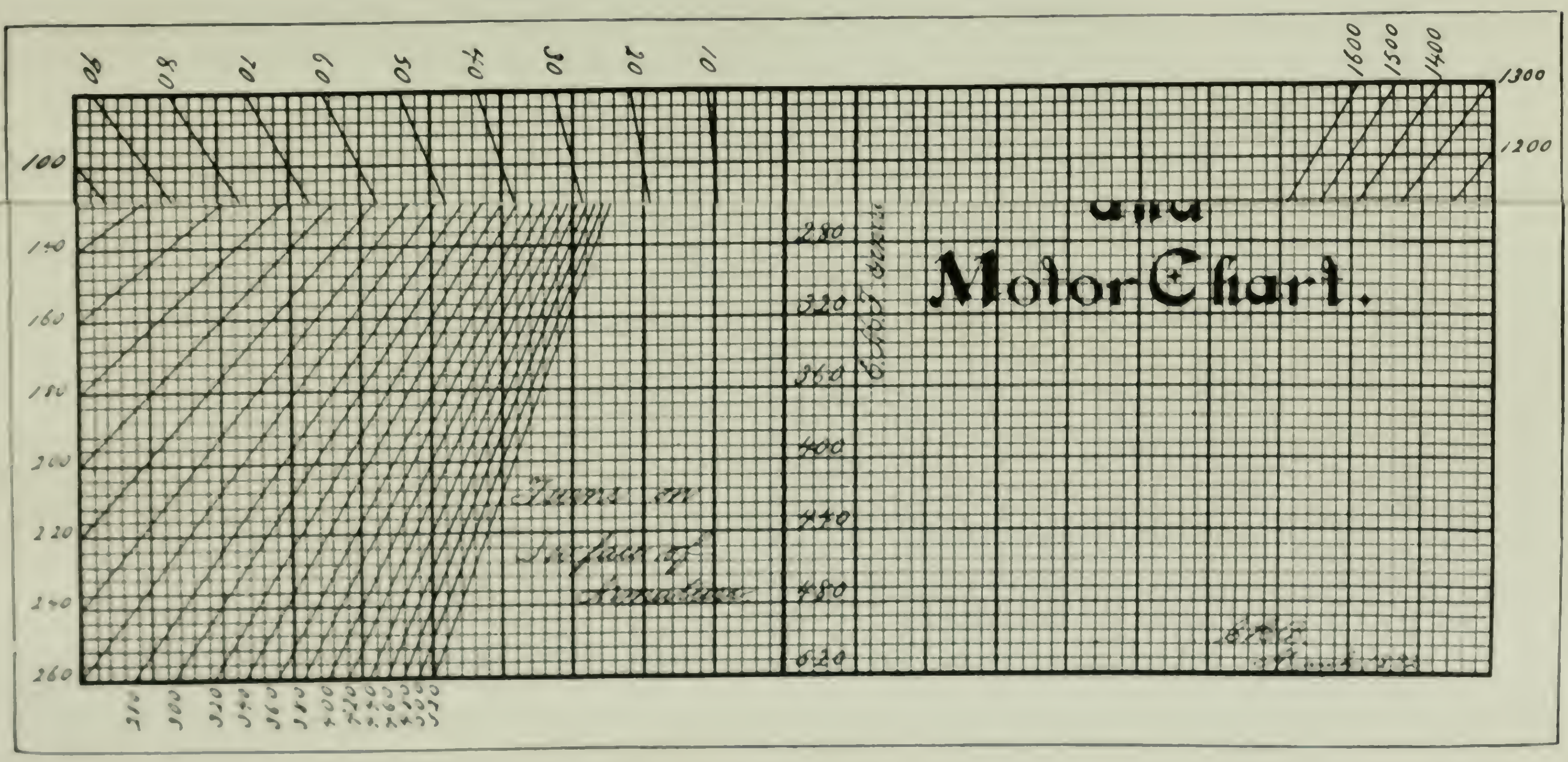
Or if very low values of E. M. F. are desired, the scale of E. M. F. can be divided by any factor, provided any one of the other scales be divided by the same factor.

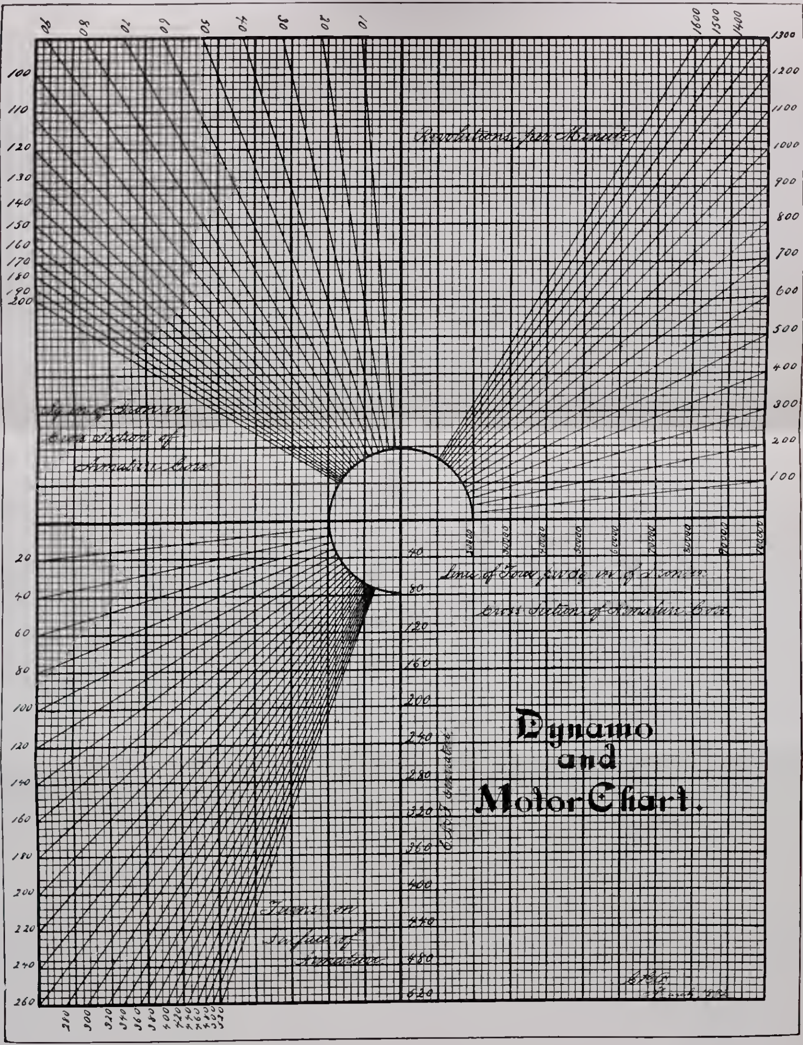
As an illustration of the use of the chart, let us suppose we have a dynamo having 200 times on the surface of the armature sixty square inches of iron in the cross-section of the armature core, and we desire to know at what speed it will be necessary to run the armature to generate 200 volts. Starting at the 200 point in the column marked "E. M. F. generated," follow the line to the left until it intersects the line representing 200 turns; then follow the vertical line from that point until it intersects the line representing sixty square inches cross-section; then follow the line to the right until it intersects the line representing the probable degree of saturation, which in this case we will say is 100,000 lines of force per square inch. The speed line which also crosses at this point is the speed required, and is exactly 1,000 revolutions per minute. If only 90,000 lines of force per square inch could be obtained, the speed required would then be a little over 1,100 revolutions per minute. It will be noticed that the form of the armature, amount of active wire, or volts per foot of active wire, do not enter into the calculation. In this method the number of lines of force which pass from any one pole into the armature core and the rate which the wires cut these lines of force form the basis of calculation.

The maximum $P_1 D_1$ is between two points on the armature wire which just include all the lines of force which pass through the armature, to or from any one pole, as at *a* and *b* in the figure, if we are working with the lines which pass from the north pole.

As far as the E. M. F. generated between *a* and *b* is concerned, it makes no difference in a ring armature what becomes of the lines of force after they pass those points, or what the other wires on the surface of the armature are doing. In a two-pole field the other portion of the armature wire, passing under the south pole, cuts the same lines of force, and consequently the same number, and since the rate of cutting them is the same, the E. M. F. generated is exactly the same as that generated under the north pole. But as these two E. M. F.'s are in opposite directions no current flows around the armature, although the points of greatest $P_1 D_1$ are joined together by the parts of the armature wire not under the poles.

Since what becomes of the lines of force after passing the points *a* and *b* of a ring armature, or what the armature wires not between *a* and *b* are doing, makes no difference to the E. M. F. generated between *a* and *b*, the lines of force may be divided so as to pass from the armature into different poles, and the armature wires not between *a* and *b*


Motor Chart.
and
90
80
70
60
50
40
30
20
10
1600
1500
1400
1300
1200
100
140
160
180
200
220
240
260
280
320
360
400
440
480
620
Turns on
surface of
armature



Dynamo and Motor Chart.

may pass under any odd number of poles, and may generate under those poles different E. M. F.'s from those under the pole first considered. It is usual, however, to so build the different portions of a multipolar field, that the E. M. F. generated under the poles is the same in amount, in order that all the terminals of the same potential may be joined together, thus connecting the different portions of the armature in parallel.

The methods of calculation given above, either by formula or chart, deal with the generation of the E. M. F. under one pole only, and consequently can be used for any direct current dynamo having a ring armature, whether for bipolar or multipolar fields.

In the case of drum armatures the conditions are a little different, as the return portion of a wire under the north pole passes under the south pole and generates an E. M. F. which is added to that generated under the north pole, increasing the E. M. F. between *a* and *b*. But the adjoining wire does not give its E. M. F. to *a* and *b*, but to corresponding points adjacent to the south pole. Consequently, it may be considered that the one wire offsets the other, and the same formula and the chart hold good for drum armatures also.

In cases of multipolar machines having the E. M. F.'s generated under like poles in series, the E. M. F., either of formula or chart, should be increased in proportion to the number of such poles.

The square inch of iron in the cross-section mentioned above has reference to the iron in the cross-section through which the lines of force pass from any one pole.

The E. M. F. generated may be that of a dynamo, or that of a motor in the form of counter E. M. F. In each case allowance should be made for the loss in voltage due to the resistance of the armature, and also to whatever loss of E. M. F. there may be due to the lead of the brushes.

BOOK NOTICES.

Woodbridge School Essays. No. I. Theoretical Astronomy. Dynamics of the Sun. By J. Woodbridge Davis. New York: D. Van Nostrand Company.

This work is apparently intended to bring before the scientific world an hypothesis by which the explanation of a number of cosmical phenomena is attempted that have heretofore defied rational explanation.

The author begins with an analytical examination of the dynamic relation existing between the atmosphere and the nucleus of an imaginary orb, the atmosphere consisting of the vapors of the fluids and solids composing the nucleus. The laws governing the evaporation or condensation or both in the several strata of the atmosphere, as dependent on the conditions of heat, are carefully evolved and analytically presented.

Upon applying the results of this analysis to the sun, the author concludes that there is evaporation but no condensation on the sun, the vapors formed possessing such a tension that the velocity attained by adiabatic expansion is sufficient to hurl the molecules into space beyond the reach of solar attraction. In order to account for the heat required, it is assumed that at the exalted temperature prevailing on the sun the so-called hemical elements are dissociated into a lower grade of elements capable of reuniting as the temperature on the surface of the nucleus is lowered to the limit of dissociation.

This outflying solar atmosphere, in reflecting the solar light, is assumed to account for the corona and the zodiacal light. Then it is shown that this current, in sweeping past the planets, dividing, as a stream of water would on encountering an immersed sphere, not only carries away portions of the planetary atmospheres ultimately denuding those orbs of the last trace of their gaseous envelopes, as shown by the moon, but, being charged with positive electricity, resulting from the process of elementary combination, this current is supposed to account for many magnetic and electric phenomena observed on our globe. And finally, by describing comets as being surrounded by atmospheres of enormous dimensions, of which a portion is swept into space, the phenomenon of cometary tails is explained.

This work, abounding with assertions of a purely hypothetical character, fails to carry conviction to the reader. Indeed, he feels that, while this theory appears to throw light on some phenomena, it precludes the explanation heretofore given to others. The theory of Laplace is reversed; progressive dispersion of the mass of the sun is put in place of progressing concentration. The student is led to ask himself why the forces, inherent in the sun, tending to disperse this mass, will not act more rapidly, since we are wont to see such phenomena take the form of sudden explosions, as exemplified by allowing the superheated water of a steam boiler to escape from its confinement. The author here avails himself of the hypothesis of the composite nature of the so-called elements and their dissociation at high temperature. No satisfactory explanation is given why the equatorial streams of the solar atmosphere should predominate to such a degree as would be necessary to account for the convergent form of the zodiacal light. Then it would be more consistent with modern notions to assume that the outlying atmosphere, on encountering a planet, would be intercepted and arrested rather than deflected and thrown aside, such deflection being always a result of decreased pressure due to reaction, and the pressure of the outlying atmosphere being almost infinitesimal, it is difficult to imagine a cause for deflection. One would therefore expect an increase of the atmospheres of secondary orbs rather than a diminution. The theory of magnetic and electric phenomena appears strained in many respects. It is by no means clear why the particles projected into space should be charged with electricity. And if such were the case, the mass of the sun must have long since been overcharged with negative, and that of the earth with positive electricity, and the admission at the end of the respective chapter that "according to the theory, the sun is becoming negatively charged, and the planets positively charged with electricity," makes an impression as if some one would admit that a drop of water may occasionally come down the Falls of Niagara. In support of the assertion that the nuclei of comets are surrounded by immense atmospheres, the records of observations are quoted according to which stars seen through the cometic vapors showed a sensible increase of brilliancy, while according to our knowledge of optics, stars seen through a refracting sphere should have shown a diminished brilliancy, except if the observer had been within the focal distance of this cosmic lens.

The analysis of the dynamics of atmospheres surrounding celestial orbs, notwithstanding the difficulties which such an abstruse subject necessarily presents, is well conceived and carefully carried out, but the theory of the outflying atmosphere of the sun is so radically at variance with modern conceptions and appears to be so replete with inconsistencies that it is not likely to find a permanent place in theoretical astronomy. H. B.

The Elements of Physical Geography, for the use of schools, academies and colleges. By Edwin J. Houston, A.M., Prof. of Physical Geography and Natural Philosophy in the Central High School of Philadelphia, etc. (Revised edition.) Philadelphia: Published by Eldredge & Bro., No. 17 North Seventh Street. 1891.

The unqualified success of the original edition of this admirable work, as evidenced by its extensive adoption throughout the country as a text book in the schools, has amply justified the warm praise bestowed upon it in the *Journal* by the present reviewer on its first appearance. The present edition is a revision of the original, which, the author explains, has been made necessary by the progress of science, which has required the abandonment of certain theoretical views and the modification of others, by reason of the expansion of our knowledge.

We are pleased to notice that the author has wisely held fast to the same general style of treatment, and to the same order of sequence of topics followed in the original impression of the work. While a careful reading of the present edition and an inspection of the illustrations reveal the hand of the judicious reviser in many places, the book retains its identity, and in its present form, we doubt not, will prove more acceptable than ever to the fraternity of teachers. W. H. W.

Brick for Street Pavements. An account of tests made of bricks and paving blocks, with a brief discussion of street pavements and the method of constructing them. By M. D. Burke, C.E. Cincinnati: Robert Clarke & Co. 1892. 8vo. Paper. Price, 50 cents.

The pamphlet above-named contains the record of what appears to be a very thorough series of tests made by the author upon fifteen samples representing as many varieties of bricks and blocks manufactured for street paving purposes. Each sample was from a different establishment, and the whole collection, the author believes, fairly represents the paving brick of the day, as manufactured in various parts of the United States.

The examination made embraced a chemical analysis, tests of water absorption, specific gravity, transverse and crushing strength, and resistance to abrasion and impact. Details of the entire work, the history of the samples, the mode of preparing them for test, the data of the tests themselves and the results arrived at, are presented in the text and in tabular form for better review and comparison.

The pamphlet contains besides this (which constitutes of course its chief value), some useful considerations from the engineer's standpoint, on the general subject of street paving, municipal methods, etc. W. H. W.

The Transition Curve Field-book. Containing full directions for adjusting and locating a curve nearly identical with the cubic parabola in transition between any circular railroad curve and tangent. By Conway R. Howard, C.E. New York: John Wiley & Sons. 109 pp. Bound in morocco, with flap. Price, $1.50.

This work is issued in convenient pocket book form, for the service of engineers engaged in the location of lines of railway. With the aid of the general table which the author gives, the engineer is enabled readily to adjust the transition curve, so as to connect with any circular curve. The application of the method is fully illustrated by rules and examples. The utility of the book is enhanced by the introduction of tables of radii, sines, tangents, versed sines and external sextants. W.

Notes and Examples in Mechanics, with an appendix on the graphical statics of mechanism. By Irving P. Church, C.E., Associate Professor of Civil Engineering, Cornell University. New York: J. Wiley & Sons. 146 pp., 138 illustrations and six plates. Price, $2.

The "notes and examples," which Prof. Church presents in this volume, are designed especially for the use of advanced students of mechanics. They are intended to illustrate the application of first principles in mechanics of solids. An appendix treats of the "Graphical Statics of Mechanism." The author's experience as a teacher has well qualified him for undertaking the difficult task of presenting his subject clearly, and in his selection of problems he has been very judicious. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 18, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 18, 1892

JOS. M. WILSON, President, in the chair.

Present, 132 members and twenty-two visitors.

Additions to membership since last report, nine.

Mr. W. S. Collins, of New York, read a paper descriptive of the system of using petroleum for fuel purposes, as practised by the Aerated Fuel Company, of Springfield, Mass., illustrating with the aid of lantern slides, the mechanical features of the same. The system consists substantially in the employment of compressed air as the vehicle for conveying the oil to the point of combustion, and spraying it into the furnace. This method permits of the location of the oil reservoir *below* the level of the furnaces, thus obviating the danger of flooding the latter with oil in the event of accident by leakage or break-down. (Mr. Collins' paper has been referred for publication).

Mr. C. J. Hexamer presented a paper giving his views of the proper method of constructing buildings designed to be used as theatres, and on the provisions necessary to be made in the interior arrangement and fitting up of such buildings in order to insure adequate protection of human life and property against destruction by fire. In connection with Mr. Hexamer's paper, Mr. Nelson, of New York, exhibited a number of specimens of various textile fabrics and wood that had been subjected to treatment by the Martin fire-proofing process. The experiments which were made in demonstration of the resistance of these specimens to the spread of fire, when brought in contact with, or held for some time directly in the flame of, a gas jet or Bunsen burner were highly successful.

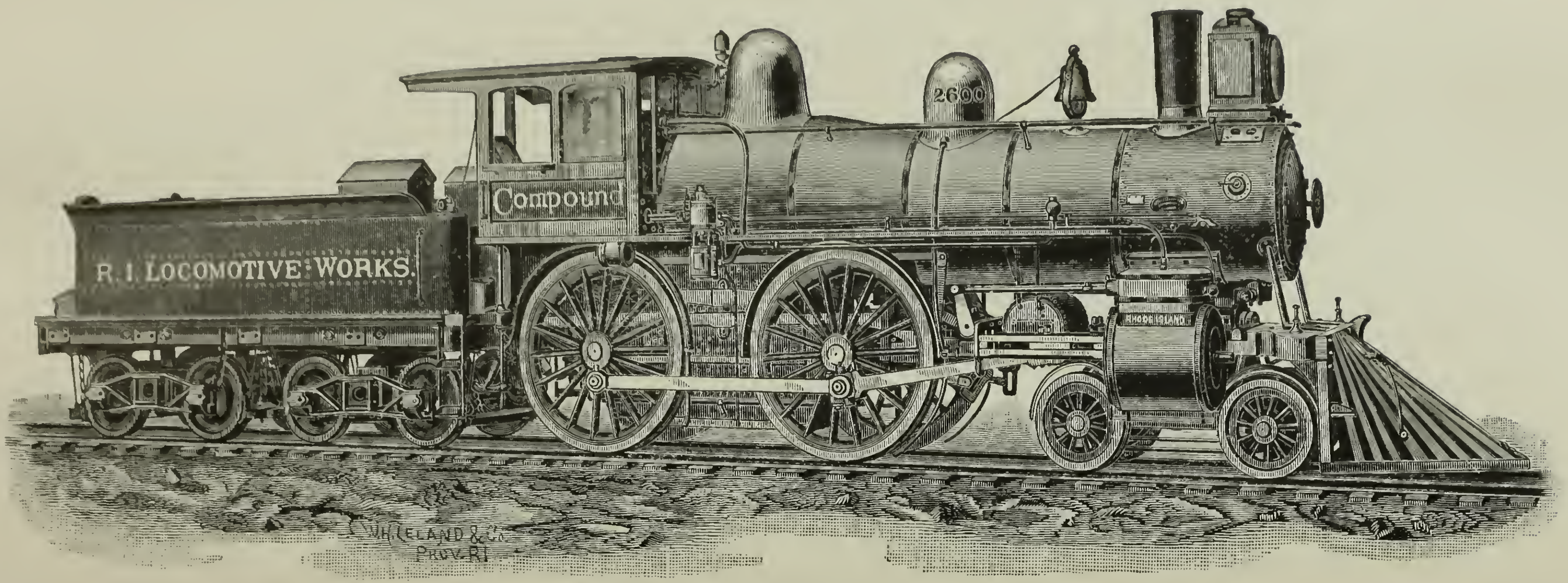
The subject elicited a general discussion. (Mr. Hexamer's paper was referred for publication.)

The Secretary presented, on behalf of Mr. Elwood Ivins, a handsomely framed set of specimens of metal tubes of steel, brass, copper and aluminum, among which were a number that were of extremely small diameter, and in lengths of thirty or more feet. These tubes are seamless, without solder or weld, and are made by a process devised by Mr. Ivins.

Mr. W. N. Jennings exhibited and described a number of remarkable lightning photographs lately made by himself. In order to permit of the more satisfactory and accurate study of the lightning image, Mr. Jennings explained that he had used for these pictures the stereoscopic camera. A number of prints of such pictures mounted in a hand stereoscope were passed about for inspection. Mr. Jennings remarked that so far as he was aware he was the first to employ the stereoscope in this work, and that he was pleased to be able to give the members of the Institute the opportunity of inspecting the first pictures of the kind ever made.

Adjourned. WM. H. WAHL, *Secretary.*

Jour. Frank. Inst., Vol. CXXXIII. May, 1892. (Supplement.) *(Com. Science and the Arts.)*



COMPOUND LOCOMOTIVE—Built by the Rhode Island Locomotive Works, Providence, R. I.

JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXIII. MAY, 1892. SUPPLEMENT

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE COMPOUND LOCOMOTIVE OF THE RHODE ISLAND LOCOMOTIVE WORKS, PROVIDENCE, R. I.

[*Report of the Committee on Science and the Arts, with Appendices.*]

[No. 1,610.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 30, 1892.

The sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination,

THE COMPOUND LOCOMOTIVE OF THE RHODE ISLAND LOCOMOTIVE WORKS.

Report, That in order to set forth the merits of this invention it has had submitted to it a record of a series of tests made under the supervision of Mr. C. H. Batchellor, chief draughtsman of said works, together with copies of diagrams and descriptions of the engines under test, which records accompany this report, and are as follows:

The engines are of a type known as two-cylinder compounds; that is, such as use the steam first in a small or high-pressure cylinder, on one side of the engine, and exhaust through a connecting pipe, within the smoke box, into the steam chest of a larger low-pressure cylinder on the other side, in which cylinder the steam is further expanded and from which it is finally exhausted through a blast pipe into the chimney in the usual way.

To this connecting pipe or receiver, between the two cylinders, is joined (forming part of the same) an automatic intercepting valve, to which is also attached an automatic differential pressure-reducing valve, an exhaust valve, and a controlling valve worked by hand in the cab. The valves constitute the essential features of this invention.

The object of this invention is to provide means whereby the engine may be started and run continuously with steam directly from the boiler, in both cylinders, each doing half the work, and each exhausting into the stack and atmosphere directly. At the will of the engineer the engine may be changed into compound-working, these valves and steam-ways being designed to effect this object automatically, according as the engineer moves the lever connected with the controlling valve.

These improvements are the invention of Mr. C. H. Batchellor, and patented by him September 22, 1891, full specifications of which accompany this report.

The operation and effects of the intercepting valve and its auxiliaries may be described as follows:

This valve being in any position and the throttle being opened, boiler steam will pass to the high-pressure cylinder in the usual manner, and also through a branch pipe to the intercepting valve, into the space between the two smaller pistons fixed on one end of the valve stem, causing the pistons to move from this end towards the larger of the two pistons, by which communication for steam is established through the inter-piston space to a pipe leading through an automatic reducing valve, and thence into the low-pressure steam chest, the pressure being reduced from any existing boiler pressure in the ratio of the cylinder areas. This position of the intercepting valve closes the low-pressure steam chest against a flow of steam from the receiver.

The three pistons on the valve-stem of the intercepting valve are so proportioned that they will automatically change to the compound position, when the pre-determined pressure in the receiver has been reached by exhausts from the high-pressure cylinder; the engine thus starts with steam in both cylinders and automatically changes to compound at a desired receiver pressure.

The engine may be changed from the compound system to the simple at any time, at the will of the engineer, by opening a valve connecting the receiver to the exhaust pipe, allowing the exhausts of the high-pressure cylinder to be ejected through the exhaust nozzles in the usual manner. The operation of this exhaust valve permits receiver pressure to enter the smaller end of the piston chamber of the intercepting valve, in order to insure the movement of the piston to that necessary to permit the boiler steam to enter the low-pressure cylinder, and close the receiver against the same, and to do this before the receiver is emptied through the exhaust.

This insures against a lapse of continuous action in the low-pressure cylinder, during the change from the compound to the simple system while running.

It is obvious that, in case of bad conditions of starting, the engine may be operated as a simple one at the will of the engineer, by opening the exhaust valve before starting, and that upon its closure the pistons will automatically take the compound position as already described.

The motions of this intercepting valve are controlled by a fluid piston brake, so that it cannot be moved except by a force superior to the fluid resistance, which the steam supplies, and it is inert wherever placed.

This engine differs from all other two-cylinder compound locomotives in this country, in having a means vided by which the engine may be worked just as a simple engine is, with an independent exhaust from each cylinder

This arrangement provides sufficient power at starting and under any condition of service for a period of time, or a distance from the starting point, which is at the will of the engineer.

This type of compound can be run as a simple engine in case of break-downs, with no more trouble than an ordinary engine.

In point of cleanliness, *i. e.*, freedom from cinders and black smoke, the compound offers a marked contrast to the simple engines.

The fastest and hardest work has called but for the most ordinary care in the lubrication of parts; one of them on trial (called No. 2600), has never shown a suggestion of heating in any of the bearings or journals, all of which are of the ordinary size, and this engine has so satisfactorily met all the requirements of heavy and fast express service that have been placed upon it for several consecutive months, that the builders believe themselves justified in claiming as a conservative estimate a saving of fifteen to twenty-five per cent. of fuel, in express service, in competition with a simple locomotive, the amount of saving depending upon the service.

These improvements can be applied to existing simple locomotives.

The slide valves are operated by Stephenson's link as applied to locomotives generally.

The possibility of using this engine as a simple one indefinitely, is also a very desirable adjunct for yard work, or short runs with many stops.

As an illustration of the softness of the blast, due to the low tension of the escaping steam after continued expansion in both cylinders, the engine practically throws no sparks during the hardest service, even with a clear passage from the boiler tubes to the atmosphere.

The application of steam power to the bearings of a compound engine is more evenly distributed than in simple ones, as is well known, which must contribute to smooth and easy running in a locomotive. This effect is apparent in the several graphical illustrations shown in this report, which speaks largely in favor of better stress effects when compared with the performance of the simple engine in same service.

We have here the most scientific development of a two-cylinder compound engine, automatically adapted to all requirements of variable service.

Your sub-committee, having examined the mechanisms and applications of these improvements in detail, as well as all the disinterested records of the same at its command, and having carefully noted and compared the devices and claims therefor, of other inventions for a like purpose, concludes this report by recommending the award of the ELLIOTT CRESSON MEDAL to Mr. C. H. Batchellor, for his invention.

JOHN H. COOPER, *Chairman*, H. R. HEYL,
JOHN E. CODMAN, H. F. COLVIN,
LUTHER L. CHENEY.

Adopted, February 24, 1892.

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

APPENDIX I.

COMPOUND LOCOMOTIVE OF THE RHODE ISLAND LOCOMOTIVE WORKS, PROVIDENCE, R. I.

In the following pages is given a description of the mechanism employed in the operation of the two-cylinder compound locomotives, built by the Rhode Island Locomotive Works; also the data and results of comparative tests regarding the economy and general efficiency of these locomotives as compared with ordinary locomotives, in the following services, each contained in a section of the folio.

SECTION 1.—ELEVATED SERVICE.

Gives the data and results of a comparative test between two locomotives in elevated railroad service; the compound locomotive being a duplicate of the simple one with new cylinders.

SECTION 2.—EXPRESS PASSENGER SERVICE.

Gives the data and results of comparative tests between different simple locomotives and a compound locomotive built by the Rhode Island Locomotive Works for fast express service.

Serious doubts having been commonly expressed as to the ability of the compound to cope advantageously with these two classes of service, this folio is prepared as the most concise and complete method by which the numerous questions concerning actual results can be answered. All results are from data verified by the respective railroad companies.

SECTION 1.—ELEVATED SERVICE.

Description of Engines.

The engines compared are No. 62 Simple and No. 58 Compound, of the Brooklyn and Union Elevated Railroads of Brooklyn, N. Y. (A synopsis of sizes is given in Table 1.) Both engines were of the Forney type, having two pairs of connected driving wheels, with a four-wheeled, trailing, swing truck supporting the tank, the whole connected to a rigid frame. This design is used to run forward or backward at will.

The compound engine was a simple engine rebuilt by the Rhode Island Locomotive Works, so far as the cylinders and their appurtenances are concerned, and is of the two-cylinder type, the cylinders being connected by a copper receiver. The cylinder sizes of the compound were designed to do the average service work, so near as it could be judged, with the best economy. The limitations which the size of compound cylinders, designed for this effect, must necessarily bring upon the starting, or even the hauling power of the engine under exceptionally severe conditions, is recognized and provided for by a device allowing the engine to be run at will as a simple engine: the steam pressure in the low-pressure cylinder being reduced from that in the high-pressure cylinder in direct ratio of the piston areas, irrespective of the boiler pressure. This allows the compound to be used as a simple engine, and greatly increases its maximum power; this becomes necessary in emergency cases only. The possibility of using the engine as a simple engine indefinitely is also a very desirable adjunct for yard work, allowing the engine to be worked to much better advantage. In ordinary circumstances the engine starts from rest as a simple engine, with direct steam in both cylinders, the cylinders having equal power. When the normal pressure in the receiver is reached, by means of the exhaust from the high-pressure cylinder, the direct steam is automatically cut off from, and the receiver steam admitted into, the low-pressure cylinder, and the engine thus thrown into the compound system. There is thus no appreciable change in power when the change from simple to compound is made, either in changing automatically or on being changed from the cab. The automatic change occurs from one-half to one revolution of the drivers. For actual performance in this respect see indicator cards, *Plates XXIII* and *XXVII*, inclusive.

SERVICE.

The service for which the engines under consideration were designed is of a severe nature for locomotives of ordinary form, and is considered much more so for a compound locomotive, being a series of starts and stops in quick succession, the profile containing many grades and sharp curves; prompt running time being indispensable. The total length of the division on which the engines were run is five miles, divided into sixteen passenger stations and two junction stations, at which stops were required at the time the compound was run on account of a rule issued between October 15th and November 24th. Trains consist of two cars during the middle of the day and late at night, and three or four cars during morning and evening hours. The running time is twenty-four minutes, with a headway of six minutes between trains during the two-car trips and five minutes during the four-car trips. See Table 2 for the number of cars hauled each trip, and the running time each day of the test.

CONDITIONS OF TEST.

The compound engine was run November 24, 1890; the simple, October 15, 1890. The engines were started from the yard at East New York at 6.15 A.M., and run six miles, with a light four-car train, to Fulton Ferry, where they commenced service, making twenty-two trips (eleven round trips) of five miles each, from Fulton Ferry to Ridgewood and return; then one trip of four empty cars to East New York, six miles, making a total train mileage of 122 miles from 6.15 A.M. to 8 P.M. The running time was kept by one watch, time being taken at each terminal; the duration of stops at regular and signal stations was not taken. They averaged about the same, both days being pleasant, the rail good, and the locomotives under trial not being held at signal stations to any unusual extent. The trip at 6.12 P.M., on November 24th, however, was an exception, trains being delayed seven minutes in the busiest part of the day, by awaiting the movements of an extra engine. This necessitated the handling of the exceptionally large number of passengers who had congregated, and required extra time at stations.

CONDITION OF ENGINES.

Simple engine No. 62, together with its crews, was selected by the railroad company as being the most economical on the road, as judged by performance sheets and competitive trials. The engine seemed in good condition, with the exception of the safety-valve, which leaked enough to show steam to a limited extent. The blow-off cock also leaked water; this was measured and accounted for.

Compound engine No. 58 had new metallic packing and leaked badly at the left valve stem. The throttle also leaked considerably.

MANIPULATION OF THE ENGINES AND PERSONS CONCERNED.

The crew who handled the simple engine were Mr. James Giles, engineer, and S. A. Sampson, fireman. These men formed part of the double crew who had handled it from the time it came on the road, and together with the other crew had demonstrated their expertness in economic running. Mr. Giles being off duty, the compound was handled by Mr. H. N. Fessenden, who ran in conjunction with Mr. Giles on the simple engine. Mr. Sampson did the firing. The management of the engines left nothing to be desired. The compound had been in their hands about ten days before the test was made, and was run entirely by the reverse lever until the first notch was reached, the throttle being kept wide open. The blower was used but once or twice on the compound, and sparingly on the simple. No. 58 was always worked compound automatically while in service.

COAL CONSUMPTION.

Weighed coal was used as follows: A new fire was used on both days, the tank was cleaned and weighed coal put in. The fire was built the night before and banked from coal outside the tank. When the fireman fixed his fire for running about 5.30 A.M., he used coal out of the tank, and continued so to do until the yard was reached at 8 P.M., when the condition of the fire was noted and the coal left in the tank weighed back. The state of the fire and steam pressure was similar each day at time of using first weighed coal. Each bucket of coal was weighed by an employé of the Railroad Company. It was all of the same quality and was free from dirt. The size of the coal was broken lump, and was of a soft anthracite quality. The coal was not wet during the test. The fire was well burned out at the end of each day, especially so on October 15th. The ashes were not weighed, circumstances not admitting of it. They showed a very small per cent. of unburnt coal each day. The compound burned its fires with a light draft on all trains. Steam was made very freely, the door being on the latch frequently, even with heavy trains, and especially so with light trains. Engines of the simple class steam freely with a light fire on light trains, but on the three and four-car trains the blast is sharp and fires heavy in order to keep up steam. The compound makes steam with a draft so light and even that it would seem able to burn pea coal with good steaming results, and a further saving in fuel expense. The quality of coal used breaks up immediately on contact with fire; and on regular engines quite an item is lost through the stack in a bright, unburnt condition, in small particles. Quantities can be seen in all places along the road where it can lodge; this dirt becomes disagreeably apparent when standing on the car platforms. The stronger the blast, the more this effect. Spark-throwing is also prevalent to quite an extent in heavy business hours. The soft blast on the compound does away with much of the waste mentioned, and throws practically no sparks on the hardest service. Continued observations on car platforms were conclusive as to the cleanliness of this engine in regard to dirt through the stack. As an illustration of the softness of the blast, it may be remarked that there was nothing in the smoke box of the nature of deflecting plates or netting, a clear passage being left from the tubes to the atmosphere. For details and summary of comparative coal consumption, see Table 2.

WATER CONSUMPTION.

The water was measured as follows: A barrel was measured as to capacity, and then placed in position so that it could be filled and emptied into the tank readily until the tank was full, the height of water in the tank being taken after each barrel full. Each barrel full made an equal rise of water in the tank, showing the regularity of the tank capacity in height. The various readings of water consumed were made by means of a large float, to the centre of which was attached a graduated stick. The difference in any two readings on this stick when compared with top of man-hole, gave the amount of water used for that time in inches. The readings were made at about the point of the centre of gravity of the plan of the tank, and always at the same place on a level track. The first reading was made in the morning at the time the first weighed coal was used, with the water in the boiler just showing in the third gauge. When the yard was reached at night, the water was gauged with the same amount in the boiler, and the same pressure of steam as at the start. During the day the water was measured each round trip at Fulton Ferry, where water and coal were taken, the water being kept at the same point in the boiler at each time of measuring. After leaving the yard in the morning, the water in the boiler of the compound engine was allowed to fall to the second gauge, and was kept there through the day to insure dry steam. On the simple engine the water was kept at three gauges through the day. The overflow from the injectors on each engine flowed into a receptacle and was measured. Each reading on the gauge stick was checked by the engineer or fireman. For details and summary of comparative water consumption, see Table 2.

CYLINDER PERFORMANCE.

Indicator diagrams illustrating the cylinder performance under the varying conditions are attached. They are taken from a series of cards made on a surface road just before the engine was placed on the elevated structure, and are each typical of its class. They were made during a run of twenty-seven miles between Providence and Kingston on the New York, Providence and Boston Railroad, with a miscellaneous freight train.

A three-fourths-inch pipe, eleven inches long, from each end of each cylinder, was connected to the indicator by a three-way cock in such a manner as to avoid abrupt turns, or small apertures; these connections were well wrapped with asbestos.

The cross-head motion was reduced by a special device of the pantograph type, calling for a string connection of but a few inches in length.

The pistons of the indicator were carefully watched and lubricated, and no signs of sticking are visible on the cards. The cards were all taken with a No. 80 spring.

The speed was taken with a revolution counter of positive action in the cab, the motion being taken from the pantograph. The steam gauge and indicator springs were tested before the cards were taken.

The valve motion is the ordinary Stephenson link as applied to locomotives generally, except the direction of its motion is reversed, the eccentrics being on the forward axle pointing toward the rear or main axle, with short eccentric rods. This was a feature that had to be contended against in endeavoring to get equal cut-offs and openings for the valves in all the various positions. For valve dimensions, etc., see Table 1.

The operation of taking a set of cards was as follows: There was a man at each indicator and a man in the cab. The latter at a desired time gave the indicator men a signal to be ready, and threw in the catch to the counter; he then gave a signal on the whistle at which the cards were taken simultaneously from each cylinder. The steam gauge and notch were noted, and at the end of ten seconds the speed counter was detached, and a reading taken. The speed was thus taken while cards were made, and cards were as near simultaneous as possible.

Steam chest lines were not taken on this day, it being desirable to use the shortest possible time in taking cards, and a previous trial having shown steam chest lines satisfactory. Cards showing these are shown on *Plates I, II* and *XXIX*.

Plates I to *XX*, inclusive, have each a set of high- and low-pressure cards, traced with the atmospheric line in common; and also a combined diagram showing the continuous expansion associated with hyperbolic expansion (full smooth curve), and with the expansion of dry saturated steam (dotted smooth curve). In the combined diagram, the front and back end cards are represented by full and dotted lines. Cards shown on *Plates XXI* and *XXII* were taken with the engine working upon the simple system. The speed at which cards 25 and 42 were taken is far in excess of what would be required, the simple system being desirable only in starting heavy trains, or running them under exceptionally hard conditions at slow speed. In these cards the admission line to the large cylinder shows the operation of the reducing valve to limit the initial pressure to a proper proportional amount, but the boiler pressure admission pipe to the large cylinder not being large enough to satisfy these speeds, the steam was wire-drawn, which gives the difference in M. E. P. between the two cylinders, as figured on the cards. The contour of the cards from the large cylinder, however, shows the proper reduction of initial pressure which the reducing valve secures at a considerable piston speed, which was the object of taking the cards at the given speeds. *Plates XXIII* and *XXVII*, inclusive, show cards made with the engine starting from rest; of these *Plates XXVI* and *XXVII* simply show the action of the reducing valve in keeping the total admission pressure on each piston alike and constant while it is acting. *Plates XXIII* and *XXV*, inclusive, show the above action and also the time of the automatic action in changing to the compound system, showing the difference in pressure in the receiver at the time of the change and a revolution later.

Plate XXVIII has cards illustrating revolutions made by an ordinary compound engine after the throttle is shut, before the passages are freed from pressure, when the reverse lever is in the last notch. In yard work this is a hindrance, and is undesirable at any time, when it is necessary to stop before the engine can clear itself of steam. This can be obviated by the use of the device which allows this engine to be used as a simple engine.

Table 3 contains results from thirty-eight cards, tabulated for easy reference. This table includes the steam weight accounted for by the diagrams; and is arranged consecutively in order of the different notches and speeds. The cards are from the same lot from which those illustrated were taken, and includes them. This table offers an opportunity to compare the difference in cylinder economy between high- and low-pressure steam under similar conditions. It also shows the water consumption to vary but little through the varying speeds under like pressures of steam at the same cut-offs.

It is believed that the table and cards embody good general results, and show to good advantage in comparison with those from ordinary locomotive practice. The loss in pressure by the passage through the receiver is small for both slow and fast revolutions. The admission line is good, and the expansion lines of the different diagrams hold closely to the curve of saturated dry steam, tending to show a small amount of initial condensation. The water per horse-power per hour, which is the test of economy, figures low even on the cards doing work at fast speeds.

This low water rate for work done, shown by cards, is verified by the result of the actual service test, in which nearly twenty-four per cent. less water was used by the compound than by the simple engine in doing practically the same work for fourteen hours. The work done by each cylinder is practically alike at the third and fourth notches, and varies by degrees in opposite ways from that point, as shown by Table 3. The design was to have the point of equal power near the point of average work. This engine with light trains works in the first and second notches, and with heavy trains in the third and fourth notches, always starting from the seventh or last notch.

The low exhaust pressure shown on all cards, at the ordinary working notches, is one cause of the water economy, and also signifies the style of action on the fire, these light exhausts occurring but twice a revolution in place of four times.

STRESS EFFECTS.

Aside from the economy in fuel and water consumption, an important result of the difference in cylinder performance between a simple and compound locomotive, under similar conditions, is that the latter should bring to bear upon the moving parts a more continuous or even stress, while subjecting those parts to loads of less magnitude at the point of maximum stress. The effect of the applied power should also be more regular in the compound engine. As illustrative of this effect, graphically, diagrams on *Plates XXX* to *XXXIII*, inclusive, give the rotative effect on each crank pin, together with the resultant effect for one revolution. The data taken for a simple locomotive, in working up these diagrams, are actual cards selected from first-class locomotives having Richardson-Allen valves, and a good steam distribution. Those for a compound are taken from No. 58, with initial pressures and M. E. P.s' to match the cards from the simple engine. These plates explain themselves, and suggest a steadier moving engine, more especially at high speeds, and the shortest cut-offs.

Plates XXXIV and *XXXV* show diagrams made from the same data, illustrating graphically the stress upon the crank pins, and hence the other moving parts, for one revolution. It will be observed that the lines representing the stresses on the compound crank pins keep within closer vertical limits than those on the simple engine, also, that the former keeps much nearer a continuous line, sudden variations in load being inappreciable.

GENERAL SUMMARY.

A reference to Table 2 shows the decided saving in water and fuel consumption, under the conditions of a fourteen hours' test heretofore described; this would be anticipated from diagram results in Table 3. Aside from the first cost and labor of handling this saving affects the time lost by the engines in coaling and taking water. The latter is of evident value on limited trains. In the elevated service it enables, in many cases, an engine which reaches the terminal late to save the time that would otherwise be used in taking water, thereby preventing the following train from being held by a signal. This was a fact noticed and commented upon by the train despatcher at the terminal where water and coal were taken.

The capabilities of the compound to equal the simple engines, in making short runs, on quick time, were fully demonstrated. This compound, by reason of its ability to be run at will as a simple engine, can equal the maximum power of a simple engine, when the small cylinder on the compound equals in size each of those on the simple, and the steam pressures are alike.

The smoothness of running on the compound, as compared with the simple, is noticeable in riding on the engines. This is explained by a comparison of the resultant rotative effects on the crank pins for the different systems, as illustrated graphically, with data, in *Plates XXX* to *XXXIII*, inclusive. This is a very desirable result as it affects the connections through the whole train.

The crank pins and reciprocating parts are not subject to such high pressures or sudden variations in stress during each half stroke in the compound, a result greatly to be desired. A comparison of stresses on the two systems, with data, is graphically illustrated in *Plates XXXIV* and *XXXV*.

Cylinder oil can be used with the best economy in the compound engine, the oil fed to one cylinder passing through both.

The cleanliness of the compound from cinders and sparks is a strong point in its favor. Its comparative stillness is also another desirable factor under certain conditions of service.

SECTION 2—FAST EXPRESS SERVICE.

Description of Engines.

The compound locomotive (No. 2600) was designed for making fast time on trains with few stops; and for a road with a level or rolling surface; the idea being to test its merits on this class of service against the ordinary type of express locomotives.

The engines used in competition with No. 2600 were No. 34, New York, Providence and Boston Railroad, and engines Nos. 136 and 173, Boston and Albany Railroad; the latter two being similar engines. The main dimensions of all three are found in Table 4 following. An inspection of these tables will show that the engines were very similar, the compound having very little advantage in heating surface, and a disadvantage in tractive power which counted against it on the heavy grades of the Boston and Albany Railroad, work for which this engine was not designed.

The action of the compound engine in starting and changing automatically to the compound system, and also the ability to run as a simple engine, are the same as described under Section 1.

Illustrations of the auxiliary and intercepting valve are shown in *Figs.* 1, 2 and 3.

SERVICE.

No. 2600 has been in successful general service on all the heavy and fast trains on the New York, Providence and Boston Railroad, between Providence and New London, a distance of sixty-four miles. The terminals are at tide water, and the intervening road has a rolling surface, there being grades each way from one-half to one per cent. The line of road is practically straight. Tables 5 and 6 give the results of competitive trials on two of these trains; that represented by Table 5 was made to show coal economy only.

The service on the Boston and Albany Railroad was between Boston and Springfield, a distance of ninety-nine miles, and was of a different nature from that on the New York, Providence and Boston Railroad. This will be seen on reference to the profile sketch following, the steepest grades on this road having bad curves. In making the schedule time between the terminals, advantage cannot be taken of the down grades to the extent of over forty-two miles per hour; and the making up of lost time is limited to five minutes each between Worcester and Springfield and Worcester and Boston; thus the time which an engine designed for a more level road might lose on a bad up-grade could not be made up on the down-grades, and but five minutes could be made up on the levels. In order to make the running time, therefore, little time can be lost on the hills. The compound, as before-mentioned, is not designed for this class of service, but, as will be seen on reference to Tables 7 and 8 following, it had no difficulty in making its time with the other engines. Its ability as a hill climber was fully recognized after its experience with these trains. This was due to its excellent staying qualities when worked to full capacity as a compound, together with its ability to get under way quickly from a bad starting place as a simple engine.

CONDITIONS OF TEST.

The competing engines on each trial were run on the same trains, the same number of days, with the conditions as nearly alike as possible, the same engineer handling each engine, enough days being taken to insure a fair average. The engineers had no experience with the compound previous to the first day of each test; but were regular runners on the competing simple engine, with the following exception: On the trial of March 16th to 21st, inclusive, the engineer had No. 34 but a few days before the test. The runs on the Boston and Albany Railroad were exceptionally hard for each engine, as the road was undergoing repairs in numerous places between Boston and Springfield, which necessitated many slow-ups and extra stops.

On the New York, Providence and Boston Railroad, the conditions were very similar for each engine on each trial, with the exception of the runs on March 20th and 21st, recorded in Table 5. On these dates the train, being an hour late from New London, was obliged to make extra station stops, besides stopping for several signals, and slowing up for the suburban trains at stations near Providence. This affected the elapsed time between New London and Providence and also the general average of running time.

COAL AND WATER CONSUMPTION.

The coal economy, as given in Tables 5 to 8, inclusive, is based on car mileage. The results are practically the same when based on ton mileage. Coal was weighed to the engine at the beginning of each trial, there being a low fire and no coal on the tank; that used by each engine includes the banking for over night. At the finish of the last run of a series, the fire was allowed to burn low, and the remaining coal in the tank was weighed back. The coal account, in all cases, was kept by an employé of the railroad company.

The quality of coal on the New York, Providence and Boston Railroad was ordinary bituminous, about one half lumps.

The coal used on the Boston and Albany Railroad was best quality of Pocahontas, well mixed with lumps.

Accurate water measurements were attempted on but one test, objections being made to the delay incident to taking accurate readings when water is taken on the line of the road. From the observations which were made, however, there is every reason to believe that the trial in which the water was measured was the one in which least was saved. This would follow from the fact that it was the lightest of the four tests in point of work done, and that in which the least coal was saved.

On the test in which water was measured, careful attention was paid to the measuring of all quantities not used in the cylinder, and high water in the boiler was guarded against. The water in the boiler water-glass, was at the same place when final tank reading was taken at the end of the round trip, as when the first reading was made, the engine standing at the same spot.

CYLINDER PERFORMANCE.

Indicator diagrams were taken from No. 2600, in Section 1; and the diagrams shown in *Plates I* to *XXIX*, inclusive, fairly represent those taken from No. 2600 under the same general conditions, the ratios of cylinder areas being the same in each case. The cylinder powers show very nearly equal.

Plate XXI shows diagrams taken for experimental purposes as explained in Section 1.

Plate XXII shows diagrams taken in the simple system, the conditions being the same as those under which it is designed to be used when run as a simple engine. No. 47, on this plate, was taken at an early cut-off to show the action at that point.

GENERAL SUMMARY.

A reference to Tables 5 to 8, inclusive, will show the saving in fuel consumption made by the compound, on each given service, running in competition with selected engines on the respective roads; the engineer in each case being the regular runner of the simple engine, but handling the compound for the first time. The engineers all claimed that they could do more justice to the compound on a longer acquaintance.

All the engines were as nearly alike as was possible under the circumstances, the cylinder action excepted; and the differences in heating surface alone were too small to affect appreciably the fuel consumption.

The compound has met satisfactorily all requirements of hard work and fast running that have been placed upon it.

In point of cleanliness, *i. e.*, freedom from cinders and black smoke, the compound is a marked contrast to the simple engines. This feature was quickly observed and remarked by the engineer and trainmen on the first trips on each new train. From this fact the question naturally arises why the compound could not be substituted for the large and heavy anthracite coal burners which are run at large expense and considerable trouble on some fast trains simply on account of the item of cleanliness. No. 2600 needs and has no netting in the smoke-box.

If the compound locomotive can be run so that the smoke and cinder nuisance is satisfactorily dispensed with, which would seem to be the case, the cost of operating it as compared with an anthracite coal burner may be illustrated from an actual case as follows: Trains 23 and 42, New York, Providence and Boston Railroad (see Table 5) have an anthracite locomotive for a regular engine; it runs 29·5 miles per ton of coal as a regular average. Another anthracite locomotive on a somewhat lighter service on the same road runs 30·5 miles per ton. Comparing the cost of anthracite fuel on trains 23 and 42, with the cost of bituminous fuel used by the compound on same trains (forty-two miles per ton), the saving in cost is forty-eight per cent., the bituminous coal costing twenty-six per cent. less delivered than the anthracite.

It is claimed that in a properly designed compound locomotive, the stress effects of the reciprocating and revolving parts should be more regular than in a simple engine, exerting the same power. (See Stress Effects, Section 1.) No. 2600 has never shown a suggestion of heating in any of the bearings or journals, all of which are of the ordinary size. The fastest and hardest work has called for but the most ordinary care in the lubrication of parts. The voluntary verdict of all the engineers is that it is an uncommonly cool running locomotive, light on oil, and easy to take care of; the latter in their estimation being quite a point in favor of the compound.

The ability of this type of compound to be run as a simple engine enables it to be run with either cylinder singly, in case of break-downs, with no more trouble than an ordinary engine.

No. 2600 has so satisfactorily met all requirements of heavy and fast express service that have been placed upon it for several consecutive months, that the builders believe themselves justified in claiming, as a conservative estimate, a saving of fifteen per cent. to twenty-five per cent. fuel on express service by a properly proportioned compound of this type, in competition with a simple locomotive, the amount of saving depending on the service; also a decided advantage in cleanliness; and freedom from heating tendencies, the latter signifying light oil consumption.

APPENDIX II.

(A) CONTAINING THE DATA AND DESCRIPTIVE MATTER RELATING TO EXISTING INVENTIONS AND MECHANISMS, DEVISED BY OTHERS FOR OPERATING TWO CYLINDER COMPOUNDS—PUBLISHED AT HOME AND ABROAD—TOGETHER WITH THE EXPERIENCE AND OPINIONS OF THE MEMBERS OF THE COMMITTEE ON COÖRDINATE BRANCHES OF THE SUBJECT.

"*The locomotive is not the invention of one man, but of a nation of mechanical engineers.*"

—ROBERT STEPHENSON

The pen of locomotive history has recorded little or nothing of practical value during the first twelve centuries of our era.

Whether the announcement of M. Pambour, made in the year 1835, that "locomotive engines were the first of all engines," be true or not, we can refer with confidence to the words of Roger Bacon, written more than 600 years ago, in which he says: "We will be able to propel carriages with incredible speed without the assistance of any animal."

The long years succeeding this prophecy were filled with "speculations wild and visionary theories absurd" (so the records tell us), down to the date of Ramsay's English patent in 1618, which, in the quaint language of the time, offers us: "*A farre more easie and better waye for the carrying of coaches, carts, drayes and other things, going on wheels, than ever yet was used or discovered.*"

Even the great Sir Isaac Newton, in the year 1680, tries his hand at inventing a road locomotive, but whether it ever passed beyond "the idea only for other minds to work upon," history is silent.

The period of fruitful experiment with locomotive engines having cylinders and pistons and the necessary valve gear with linkages to cranks, begins with a French engineer, named Cugnot, in the years 1763 to 1770, and was continued by Murdock in 1784, and by Trevithick and Vivian in 1800, who at once solved the problems of high-pressure steam and simplicity of construction. Our "Watt of America"—Oliver Evans—in 1804, built that odd machine which was at home on land or in water, and, in common with Murdock, used the "grasshopper engine," with vertical steam cylinder.

Gurney's steam coach of 1828 is interesting as showing a horizontal cylinder having rod connections from a piston to a cranked driving-wheel axle, upon which is an eccentric for working the valve, arranged for cutting off at half stroke and with a link for reversing. He also used one of the earliest "sectional boilers," in which he carried steam of seventy pounds pressure per square inch.

But when the celebrated Rainhill trial came off in October 6, 1829, Stephenson's "Rocket" held the track alone, having more than performed all the stipulated conditions. This was the result of Stephenson's resolve in 1813 to make himself thoroughly acquainted with what had already been done, and of subsequent application to accomplish the grand object of inventing an efficient and economical working locomotive.

Much of this history was, of course, interlined with inventions, which, like pure intents, came to nothing; many were worthily conceived, but were bad in construction, and for want of proper tools and ripeness of time were never repeated.

Stephenson's "Rocket" achieved a great victory, impressing the assembled multitude, on the occasion of the great trial, as well as the people throughout the whole kingdom. It ushered in a widespread railway mania, taking precedence over every other enterprise.

"Nothing will beat the locomotive," says Stephenson, "for efficiency in all weathers, for economy in drawing loads and for power and speed as occasion may require." We need not ask as to the fulfilment of Stephenson's prediction. It is everywhere, in every country, amply verified.

The locomotive, with two equally sized high-pressure cylinders, improved and perfected from the Stephenson model, which "held the road" in his day, is well nigh the universal type of our time.

Let us right here be particular in our statements regarding the earliest conception and development of the two-cylinder compound steam engine. There have been many opinions published concerning the origin of this important invention. We make no further apology, therefore, for setting this matter aright, and quote Mr. Wm. Pole's conclusions from his thorough study and publication of them in *Newton's London Journal of Arts*, for August, 1863:

"The double-cylinder engine was invented by Jonathan Hornblower, a mechanical engineer of considerable eminence in Cornwall, who took an important part in the application of the steam engine in that district, during the early part of Watt's career. The idea appears to have occurred to him early in the year 1776, if not before.

"He experimented upon a large working model. The cylinders of which were eleven and fourteen inches diameter, respectively; and he published his invention in 1781, describing it as consisting in the employment of two steam cylinders—the steam after it had acted in the first cylinder being employed a second time in the other, by permitting it to expand itself; the two cylinders being connected together by suitable steam ports and valves. At the same time, he described also, shortly but clearly, several other inventions relating to the steam engine. One referring to surface condensing, which is so much applied in modern days; others to means of getting rid of the air and condensing water; and another invention was a steam piston, which altered into a steam stuffing-box, is in common use at the present time. Here, therefore, was clearly developed the theoretical principle as well as the practical application of the expansion of steam; and it is beyond dispute that the first publication of the principle to the world was this of Hornblower's."

Dr. Thurston, in his *Growth of the Steam Engine*, says: "Richard Trevithick was the first engineer to apply steam power to the haulage of loads on the railroad."

Mr. Samuel Smiles, in his *Lives of the Stephensons*, recorded the following important departure from almost universal previous practice: "In Trevithick's engine, the piston was not only raised, but was depressed by the action of the steam, being in this respect an entirely original invention and of great value."

"Mr. Trevithick knew of Mr. Hornblower's double-cylinder engine in the year 1792; he had spoken to Davies Gilbert in 1796 on the possibility of making an engine to work by the force of steam."

"An old account book of Trevithick's, dated 1800, gives the detail items in the manufacture of the first steam carriage." "It was in progress in 1800, and on Christmas-eve, 1801, conveyed the first load of passengers ever moved by the force of the steam."

"Trevithick's high-pressure engine, which was worked by the force of steam, sixty pounds or more to the square inch.

"One of the gains from the Trevithick's high-pressure engine was its portability and cheapness.

"This engine had little or no resemblance to any steam engine that had preceded it.

"The boiler was cylindrical, in which the steam cylinder was fixed; the tubular boiler flues were of wrought iron, and entirely within the boiler.

"The exhausted steam having done its work in the cylinder, at a pressure of sixty pounds to the inch, passed into the chimney as a steam blast, causing an intensely hot fire, and in its passage heated the feed water.

"A patent was granted on the 24th of March, 1802, to Richard Trevithick and Andrew Vivian, for steam engines for propelling carriages, etc., which may be read and studied by the young engineer with pleasure and profit, even in this age of greatly-improved steam mechanism."

Mr. Trevithick, in the year 1802, made engines having two steam cylinders, which were connected to cranks at right angles, and they used the "blast-pipe;" such engines were called "puffers."

These engines were the first of the high-pressure double-cylinder type used in Cornwall. Mr. Trevithick's patent of 1802 recommends the use of two cylinders.

"The specification of the patent granted to Messrs. Trevithick and Vivian is descriptive of a high-pressure engine, the most simple and effective ever known." "It exhibits in construction the most beautiful simplicity of parts, the most sagacious selection of appropriate forms, their most convenient and effective arrangement and connection; uniting strength with elegance, the necessary solidity with the greatest portability, possessing unlimited power, with a wonderful pliancy to accommodate it to a varying resistance; it may, indeed, be called *the steam engine*."

From D. K. Clark's *The Steam Engine*, 1890, vol. iv, p. 647, we take a few paragraphs containing important references:

"It appears that the receiver type of engine was introduced and brought prominently forward by Mr. E. A. Cowper, who states that 'about the year 1838, a small steamboat, the *Era*, had a high- and low-pressure cylinder, with a pipe connecting them and cranks at right angles.'"

From Mr. Thomas Craddock's book, called *The Chemistry of the Steam Engine*, published in London in 1848, we make the following extracts:

On p. 51 he says: "Owing to the superiority, as it appears to me of two cylinders instead of one for the most economical use of steam expansively, I turned my attention to the combining in the simplest and most compact manner these two cylinders, so as to prevent as little loss of steam, by cooling and useless expansion between the two cylinders as possible. For this purpose I devised what I would designate the *twin-cylinder engine*, having one valve serving for the ingress and egress of the steam into both cylinders. By this means we make *one* eccentric, *one* valve, *one* cross-head, and *one* connecting-rod, with *one* steam-box, serve the purpose of both cylinders."

In the month of April and year 1844, Mr. Craddock made experiments with a compound engine of his own designing, which he says is "the *first* engine ever constructed on the principles I am here treating of, which are those of condensing by *air* with the production of a *vacuum*."

The extent of the vacuum obtained by these means—a revolving fan wheel—was eighteen inches.

"On the application of the invention under discussion to locomotive engines, I have thought much, as we had at one time determined on constructing a locomotive upon the principles I have set forth."

"The best mode, as it appears to me, of applying these principles for locomotive purposes, would be to construct a tubular boiler, having several ranges of tubes." * * * "I should also propose that, to insure the most economical use of the steam, the *twin cylinders*, of which I have before spoken, be fixed much in the same way as the cylinders are at present. We should then have a combination of the high- and low-pressure engine moving itself and a train along our railway." "Another thing to be desired, which would result from such locomotives, as I am here speaking of (with air condensation and return of condensed steam to the boiler again) is, that we should have no noise from, or even *appearance* of steam."

Mr. Craddock further states that, with his twin engine of six and fourteen-inch cylinders combined with his air condenser, by which he obtained a twenty-four inch vacuum, thus realizing his anticipations; he also performed a double quantity of work with the same quantity of steam. "I have fixed upon 115 pounds as the pressure of steam in the boiler, because that is the pressure I have used. But many years will not pass before 200 pounds pressure per square inch will be used, and this with almost total exemption from danger."

Mr. Craddock's patent universal condensing steam engine bears date the 3d of December, 1846, and embodies a claim for the adaptation of double-cylinder engines, attached to separate cranks, to railway locomotives, and a claim for the adaptation of the angularly-set double-cylinder engine, attached to a single crank, to railway locomotives. He further says more specifically, "I claim, in relation to all that class of high-pressure engines in which steam of a high pressure is used in one small

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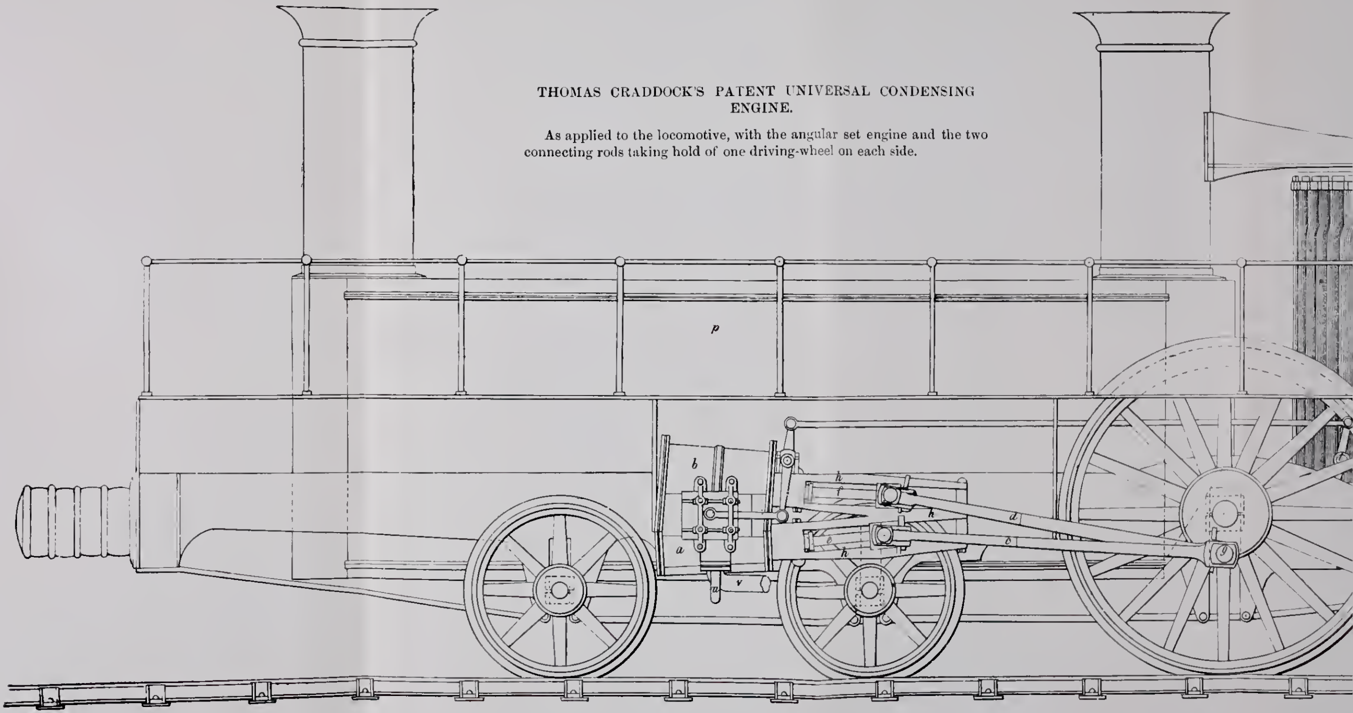
THOMAS CRADDOCK'S PATENT UNIVERSAL CONDENSING ENGINE.

As applied to the locomotive, with the angular set engine and the two connecting rods taking hold of one driving-wheel on each side.



(*Com. Science and the Arts.*)

VERSAL CONDENSING

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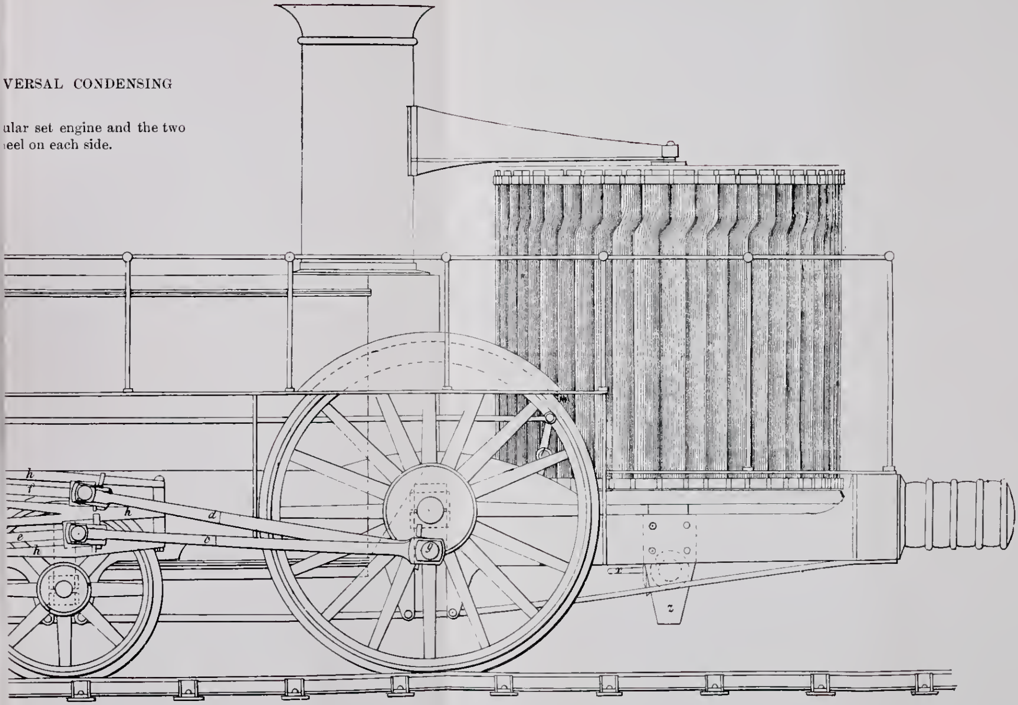
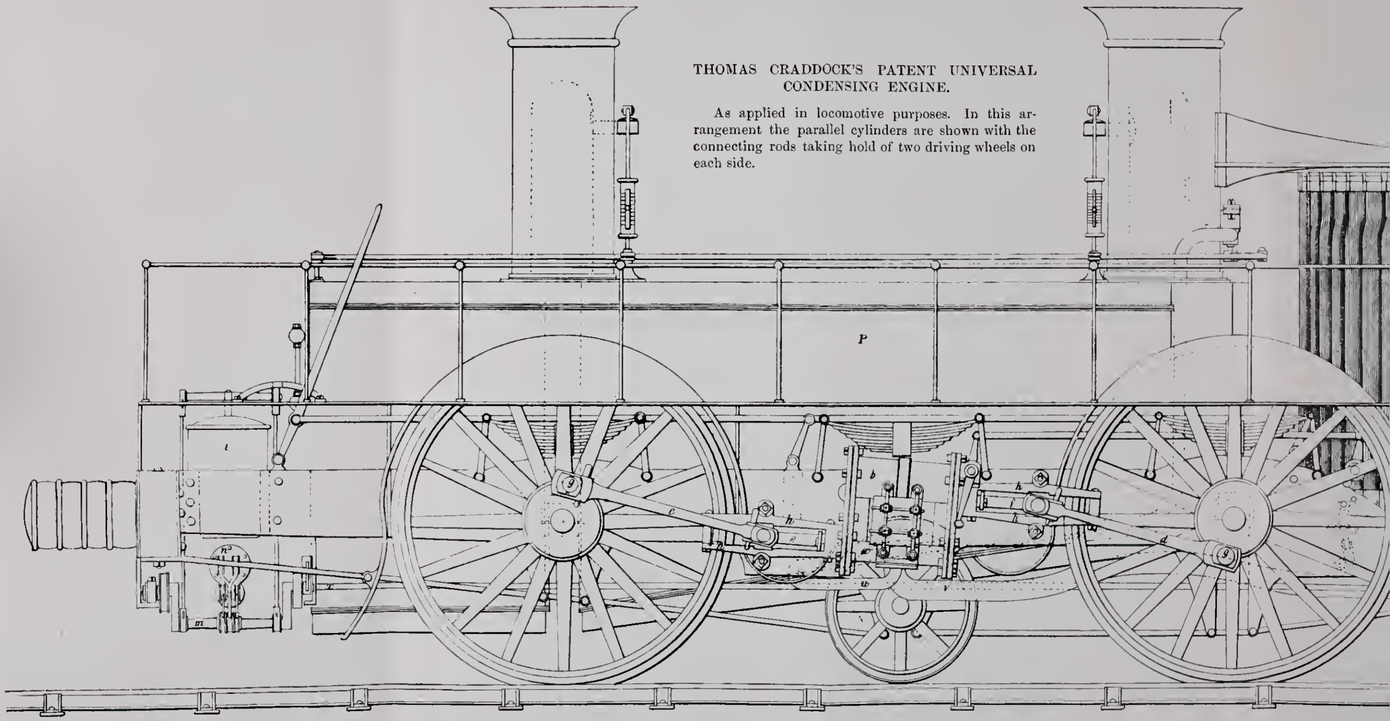


Jour. Frank. Inst., Vol. CXXXIII. May, 1892. (*Supplement.*)



THOMAS CRADDOCK'S PATENT UNIVERSAL CONDENSING ENGINE.

As applied in locomotive purposes. In this arrangement the parallel cylinders are shown with the connecting rods taking hold of two driving wheels on each side.

(*Com. Science and the Arts*)

CK'S PATENT UNIVERSAL ENSING ENGINE.

comotive purposes. In this ar-
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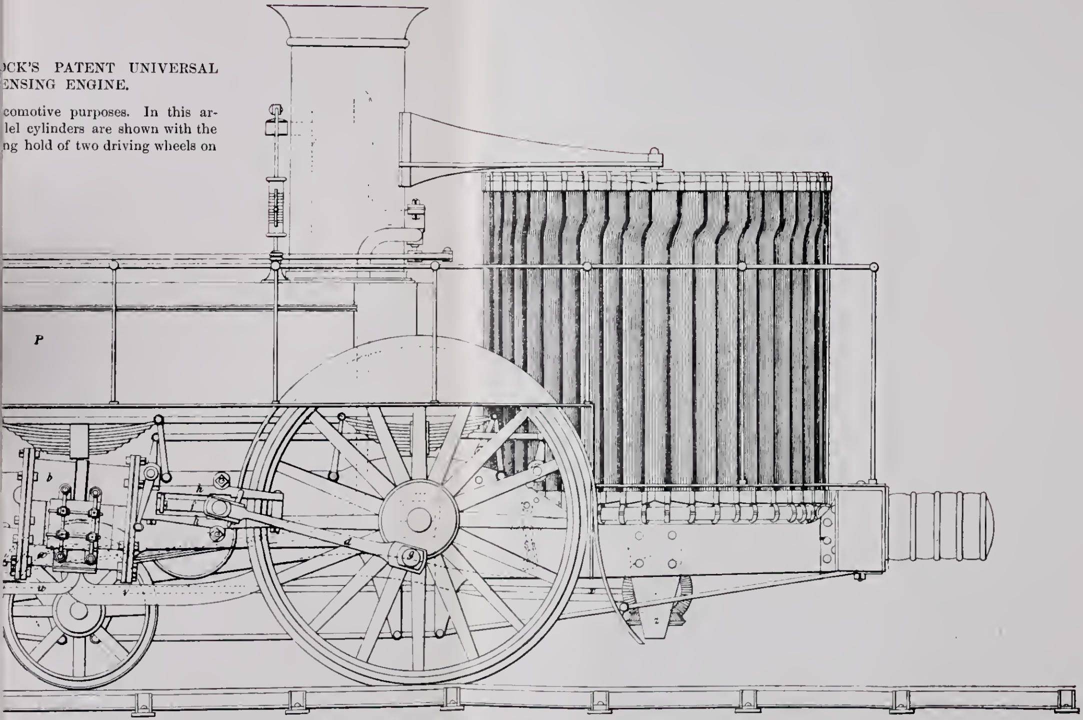


cylinder, and then expanded into a second and larger cylinder, the setting of the cylinders at an angle and connecting them to one crank pin, whether combined or not combined with my other improvements, all or any of them, and in whatever position the said cylinders may be fixed in other respects, as horizontally, vertically or obliquely."

Mr. Craddock's book, published in London in 1847, giving full descriptions of his engines, is illustrated by ten large folding plates of general and detailed views, well and handsomely executed. Three of these plates represent railway locomotives, with two cylinders, a high- and a low-pressure on each side of each engine. In one of them, with parallel-located cylinders, each cylinder is connected to a crank of its own—two to a forward and two to a backward driving axle; in the other, both cylinders on each side, angularly set, so that the axis of each passes through the centre of the driving axle, connect to one crank and to one driving axle; the former having four driving wheels and the latter two, no side rods on either. Illustrations of both these types of construction are given herewith, which sufficiently explain themselves.

Mr. Craddock says: "I ask the reader carefully to note how every principle, which is desirable for economy both in fuel and boiler is embodied in the locomotive represented in the drawing. There we have great extent of grate, low state of combustion, great extent of surface, water free from deposit, the blast not required, the atmosphere removed from the exhaust side of the piston, safety from explosion, every facility for raising the pressure higher at which the steam is generated, a less tendency to priming, every facility for carrying out the expansion principle, the tender dispensed with, the engine of less weight, no steam blowing away at the safety valve, supplies of water not required further than a few gallons per day to make up for leakage. In short, here is every principle requisite to the most perfect, the most economical engine. Never did more sound principles combine to invite a fair trial of any machine than this invention exhibits."

Mr. Craddock proposed to produce steam without blast, by increasing the grate surface to make up for this loss, he would thus secure a quiet running and clean engine. He condensed all the exhaust steam in an enclosed air fan wheel, returning all the water of condensation back to the boiler for reconversion into steam. He used tubular boilers, which afford thin metal, with large extent of surface, supplied pure water to the boiler and thus avoided "deposit," condensed the steam, thus availing himself of the benefit of expansion at the *best* end of it.

The locomotive cylinders have a diameter ratio of 4 : 10 with stroke of 12; driver diameter of 52 and gauge of rails 55½. (No scale on drawings.)

Mr. Craddock certainly conceived many happy engine thoughts, and published much data having creditable simplicity, well worth our study. His theories and principles of construction are well marked with many lines of perfection, and considering date and conditions, his eight years and more of daily experimentation, fraught as they are with results, deserve well of our praise.

Mr. F. W. Crohn, in *Proc. Inst. M. E.*, London, 1879, p. 357, said the "continuous expansion" system was the invention of Mr. John Nicholson (in the year 1850, the same as Samuel's, referred to later on), and engines on that principle were to this day made in considerable numbers at the Blackwall Iron Works for marine purposes.

These engines have been much simplified; they have no receiver and have but one valve to each cylinder, the steam going direct from the high-pressure cylinder into the valve chest of the low-pressure.

The first locomotive built on this system showed an economy of twenty per cent. of coke over ordinary engines, when cutting off at one-third, the work performed being equal in each case, the cylinders were 15 and 17½ inches diameter, giving a ratio of 1:1·36 of area.

Mr. James Samuel's patent bears date April 5, 1850, in which claim 8th describes steam engines adapted for economizing steam and fuel. "Their cranks are placed at right angles with each other or nearly so, and with two or more cylinders. A portion of the steam admitted into the first cylinder is caused to pass into the second, and if more cylinders be used, the steam is passed in both cylinders in succession.

9th. "A hollow slide-valve with metallic packing and springs, to allow steam from the exhaust to pass through the back of the valve." For details, of which see *Mech. Mag.* for 1850, p. 403, London.

Extracts from a paper, by Mr. James Samuel, of London, *on a continuous expansion steam engine*, from Proceedings of the *Institution of Mechanical Engineers*, Birmingham, England, January 28, 1852:

"The economy of working steam expansively is well known, but the application of the expansion principle is practicable only to a limited extent in most forms of engine, from practical difficulties in their mode of working, which prevent the attainment of the full economy of which the expansive principle is capable."

"In the locomotive engine there are practical difficulties in carrying out the expansion principle efficiently, beyond a moderate extent, in a single cylinder, from the shortness of stroke and rapidity of reciprocation and the construction of the valve motion; but the ultimate extent to which it could be carried would be limited by the maintenance of the blast, which requires that the jets of steam discharged from the cylinder into the blast pipe should not be reduced below a certain pressure at the moment of discharge. Otherwise, the limit to which expansion might be carried would be the resistance of the atmosphere to the discharge of the steam, added to the friction of the engine, say about ten pounds per inch above the atmosphere."

"The steam is cut off usually by the link motion at from one-third to two-thirds of the stroke, and the steam is consequently discharged into the blast pipe at about from thirty to sixty pounds pressure above the atmosphere, supposing it to be supplied to the cylinders at 100 pounds per inch above the atmosphere."

"It appears that the lower of these pressures is sufficient, or more than sufficient, for the purposes of the blast, to maintain fully the evaporative power of the boiler under general circumstances, and that a portion of the steam discharged can be spared from the blast to be subjected to a greater extent of expansion."

"In the continuous expansion engine, the subject of the present paper, the steam from the boiler is supplied only to one cylinder; a portion of it is expanded into the second cylinder, which is of proportionately larger area, so as to equalize the total moving power of the two cylinders; and it is there further expanded down to the fullest useful extent, and then discharged into the atmosphere, the portion of steam remaining in the first cylinder being discharged as a blast at nearly the same pressure as the ordinary engines. The economy, therefore, consists in obtaining from such portion of the steam as can be spared from the blast, the additional power of expansion remaining in it, which is thrown away in the ordinary engine."

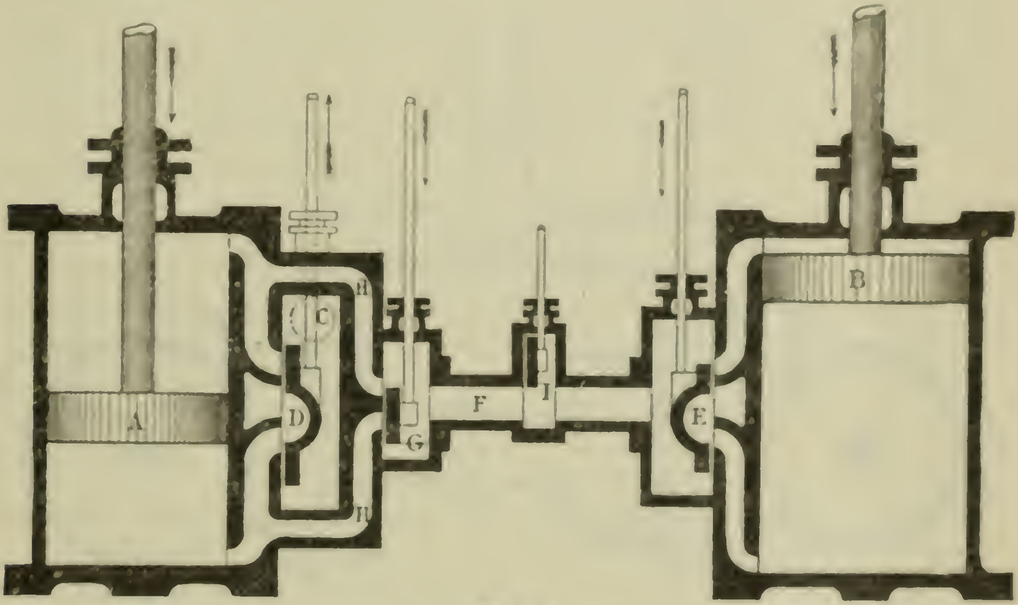


Fig. 4.

Figs. 4 and 5 show the continuous expansion engine as applied to a locomotive. *A* in the first cylinder into which the steam is admitted from the steam pipe. *C*, by a valve *D*, in the same manner as in the ordinary engines. The steam is cut off at half-stroke, and a communication is then opened with the second cylinder *B*, through the passages *H* and *F*, by the opening of the slide valve *G*. The second cylinder *B*, is about double the area of the first cylinder, and the same length of stroke, but the cranks are set at right angles, as in ordinary locomotives; consequently, at the moment of the steam being passed into the second cylinder from the first, the piston of the second cylinder is at the commencement of its stroke."

The steam continues expanding in the two cylinders until the first piston *A* has nearly completed its stroke, when the valve *G* shuts off the communication between the two cylinders, and the valve *D* opens the exhaust port, and communicates with the blast-pipe *L*, discharging the steam remaining in the cylinder *A*, to form the blast in the ordinary manner. The second piston *B* has then arrived nearly at half-stroke, and contains nearly one-half of the total quantity of steam originally admitted to the first cylinder. This steam is further expanded to the end of the stroke, and then discharged into the blast pipe *L* by the valve *E*, opening the exhaust port.

The return stroke of both pistons is exactly similar to the foregoing, so that about one-half cylinder full of high-pressure steam (or such other portion as may be desired), is supplied to the first cylinder at each stroke, and between one-half and two-thirds of that steam is discharged at the pressure required to produce the blast, and the remainder of the steam is expanded down in the second cylinder, so as to give out all the available power remaining in it.

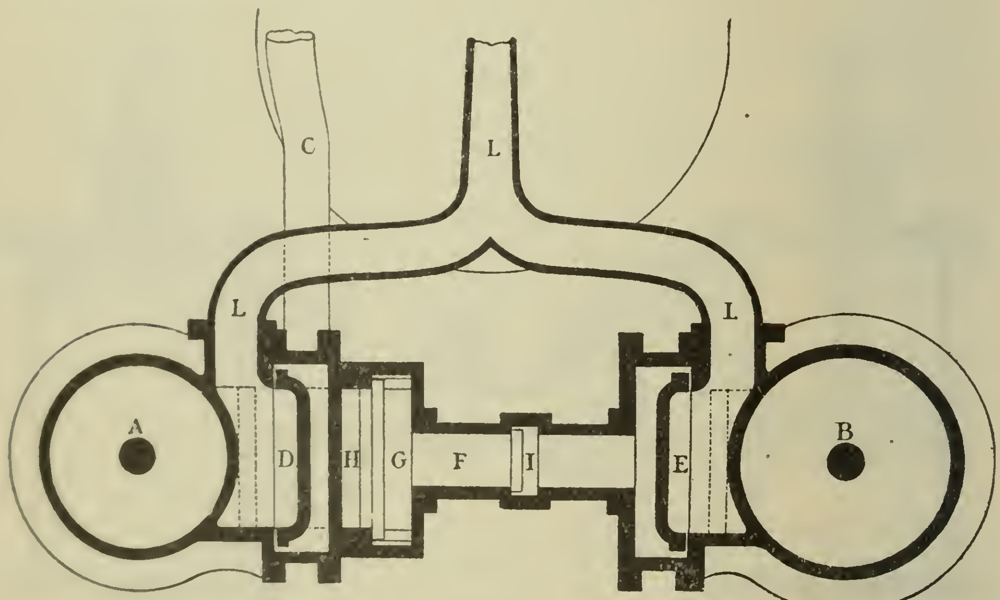


Fig. 5.

For the purpose of enabling the engine to exert an increased power, if required, at the time of starting a train or otherwise, the slide valve *I* is inserted in the centre passage *F* to close the communication between the two cylinders for a short time when required, and the steam from the boiler is then admitted by a pipe and cock into the steam chest of the second cylinder *B*, which is then worked independently of the other cylinder, like an ordinary engine.

"The comparative quantity of steam or of coke required to perform the same work in the several engines, under the circumstances stated above, is given by calculation as follows:

Continuous expansion engine,		100
Ordinary engine cutting off at,	⅓ stroke,	120
" " "	½ "	154
" " "	⅔ "	185
" " "	⅞ "	220

"These figures represent the relative economy in the employment of the steam in the several engines; consequently, the ordinary engine, with the best degree of expansion, or cutting off the steam at one-third of the stroke, consumes twenty per cent. more coke than the continuous expansion engine, to do the same work, and from fifty-four to eighty-five per cent. more coke with the more usual degrees of expansion; and an engine cutting off the steam at only one-eighth of the stroke from the termination, as many engines were formerly made, would consume 120 per cent. more coke to do the same work."

"This plan has been tried upon two locomotives with satisfactory results, and the blast was found to be quite satisfactory, when working the regular passenger and goods trains at full speed.

"One of the engines tried was a goods engine of the largest size, on the Eastern Counties Railway; the valves only were altered, and the second cylinder was not enlarged. It was only a temporary experiment, which, of course, caused a reduction in the extreme power that the engine could exert and the object was more particularly to see how the principle could be best carried out in practice, and whether the proposed reduction in the blast could be effected; the result was a saving of twelve pounds of coke per mile in consumption."

The steam was only supplied to one cylinder instead of two, and therefore so much less consumption of steam would take place.

Mr. Samuel explained that the engine did the same usual work during the trial as before; the engine driver could work the engine in the ordinary manner up the inclines by shutting the communication between the two cylinders, or the engine could not probably have taken the load through the trip, but he might be using more steam than usual in the one cylinder by keeping the regulator more open.

Mr. Samuel further said: That in the two engines that had been tried, no difficulty appeared in making steam, and they were not found short of steam. Goods engines working at slow speed might, perhaps, be found the most useful cases for applying the principle. The other engine that had been tried was a passenger engine, in which the second cylinder was made double the area of the first; and it was never found short of steam, though running an express train of considerable weight. * * * The only definite result obtained was with respect to the sufficiency of the blast, which proved quite satisfactory during the regular passenger train work of about a month.

It was remarked there was one novel circumstance in the arrangement of the proposed engine, which did not appear correct in theory; in all the previous double-cylinder engines, the first piston was allowed to complete its stroke before the steam was expanded into the second cylinder, but in this engine the steam is passed into the second cylinder at the middle of the stroke of the first piston, thereby taking the steam away at the very moment that it is most efficient in the small cylinder.

Mr. Samuel explained that at the half-stroke of the first piston the second piston was at its dead point, and began to move very slowly when the communication was opened between the two cylinders, and consequently took very little steam, whilst the first piston moved through the greater portion of its remaining stroke; but then, as the first piston was getting less effective and approached its dead point, the second piston came gradually into full action, making a *continuous* expansive action, which was the peculiar feature of this engine, instead of the *intermittent* expansion of the other double-cylinder engines.

This was borne out by the diagram taken; showing a nearly continuous line of expansion from beginning to end of the stroke; and the great uniformity in the total moving power of the two cylinders was shown in diagram also.

For these and other details, see original articles in *Mechanics Magazine*, London, 1850, and the paper quoted above.

Mr. D. K. Clark says that, judging from the results obtained, the capabilities of Mr. Samuel's system of working steam expansively were superior to those of any other that had fallen under his observation.

(*B*) DATA RESPECTING ENGLISH, FRENCH AND UNITED STATES PATENTS, WITH PARTICULAR REFERENCE TO SUCH DEVICES AS RELATE TO THE SUBJECT OF THIS REPORT, ARRANGED CHRONOLOGICALLY.

The foundations of the compound locomotive engine were laid in the year 1776, by Mr. Jonathan Hornblower, who invented and built a steam engine in that year and patented the same in 1781. In this engine the steam, after working in the first cylinder, was exhausted into the second one, which was made larger than the first, thus permitting additional expansion of the steam. In this engine the pistons of both cylinders were connected to one working beam, and, therefore, both pistons moved in the same direction at the same time.

In the year 1838, Mr. E. A. Cowper employed a compound engine, the two cylinders of which were connected by a "receiver" and the pistons were connected to two cranks at right angles to each other. Many experiments were made for determining the proper size of the receiver and the losses of heat by radiation and otherwise.

The direct application of compound steam cylinders to locomotives is clearly and elaborately shown by Mr. Thomas Craddock, and patented by him in the year 1846, but we are not aware that his engines were put upon the road, and for this reason the honor of first inventing and also running a compound locomotive belongs to Mr. John Nicholson (a "driver"). This type of engine was further improved and patented by Mr. James Samuel in the year 1850.

The English patent of Frazer Selby, September 9, 1862, shows annular cylinders proportioned in area, 1 : 4½; also two cylinders side by side of same proportion. There is no provision for starting or of equalizing the total pressure in the two cylinders. His drawings are well proportioned and admirably worked out in detail.

"About the year 1870 the Remingtons, at their works in Ilion, N. Y., built a compound steam car for the Worcester and Shrewsbury Railroad Company for suburban traffic. Two cylinders were used with means of supplying boiler steam to the larger cylinder as occasion required. This engine gave good satisfaction until its withdrawal from service a few years ago." These facts are stated by Mr. W. F. Dixon, of Paterson, N. J., in *Trans. Soc. A. S. M. E.* This is Mr. Wm. Baxter's engine, in which a special slide valve, located in the high-pressure steam chest, was used (under control of the engineer), for admitting boiler steam to the low-pressure cylinder and at the same time permit the exhaust of the high-pressure cylinder to escape into the chimney.

The United States patent of Wm. S. Hudson, dated March 11, 1873, claims:

(1) A superheating vessel, located in the smoke-box.

(2) The arrangement of the smoke-box superheater with connections to the two steam cylinders, such, that live steam from the boiler shall

enter one cylinder and be exhausted therefrom into the other cylinder through the said superheater.

(3) A locomotive having a secondary live steam pipe (provided with a controlling valve which may be operated from the foot board) leading to the second cylinder in combination with the main steam pipe leading to the other cylinder arranged for joint operation, relatively to the boiler.

When the controlling valve in the secondary live steam pipe is closed, boiler steam is admitted only to the small cylinder.

The exhaust from the small cylinder is only through the superheater into the steam chest of the larger cylinder.

This invention provides for no independent exhaust pipe to the atmosphere from the small cylinder. It exhausts only into the steam chest of the larger cylinder, so that if this cylinder were disabled, there would be no means of exhausting from the small cylinder, except through the larger by removing its slide valve.

If live steam be permitted to flow without control into the steam chest of the larger cylinder through the secondary live steam pipe, according to the third claim of this invention, this steam chest being in free communication with the exhaust pipe of the smaller cylinder, there will result a back pressure in the smaller cylinder by reason of boiler steam filling its exhaust pipe.

The consequence of this will be the larger cylinder will do more work than intended, and the small cylinder will do little or no work at all.

There is no hint or suggestion of a means whereby the engineer may know definitely the quantity or the effect of the steam he has admitted to the larger cylinder, and no automatic devices for properly taking care of it.

The English patent of John N. Coxon, June 24, 1874, shows cylinders and valves only. It admits steam to low-pressure cylinder directly from boiler. Exhausts from high-pressure cylinder directly to atmosphere. He claims a hollow valve to permit exhaust from high-pressure cylinder directly through the same to the steam chest of the low-pressure cylinder, same as was done by Samuels in 1850. No equalizing of pressure on the two pistons is mentioned.

The French patent of A. M. Mallet, October 10, 1874, shows a compound locomotive with two tandem cylinders, placed in centre of locomotive under the smoke box.

It is provided with a slide valve, whose chest is outside of the smoke-box, with stem extended to the cab under control of the engineer.

This slide valve, *in one position*, will permit boiler steam to enter the low-pressure cylinder, when the exhaust from the high-pressure cylinder is escaping to the atmosphere, while at the same time boiler steam is entering the high-pressure cylinder as usual when the throttle is open.

In *the other position* no boiler steam can enter the low-pressure cylinder, but the high-pressure exhaust is closed to the smoke-box, and is directed to the low-pressure cylinder, while this cylinder exhausts directly into the atmosphere.

A small spring loaded valve is attached to the steam way to the low-pressure cylinder (in sight of the engineer), so that when it blows off he can regulate the admission of boiler steam to the low-pressure steam chest. This valve is loaded to a pressure of equal to four-tenths or five-tenths the normal boiler pressure.

The English patent of Henry P. Holt, November 6, 1876, uses an automatic intercepting valve between low-pressure steam chest and the receiver. No mention is made of reducing valve to equalize the total pressures in the two cylinders.

The French patent of Alexander Arson, of Paris, May 13, 1878, is a two-cylinder compound engine, having a slide valve, worked by an eccentric which is operated by hand for regulating the flow of live steam into the steam chest of the low-pressure cylinder for starting.

The English patent of Thomas Robertson, January 1, 1881, is for a two-cylinder compound provided with means of injecting a jet of boiler steam into the low-pressure cylinder. No mention of steam reducing valve.

The United States patent of Henry D. Dunbar (a four-cylinder tandem compound locomotive), dated April 24, 1883, is provided with an independent *D* slide valve (on three ports) moved by the engineer in the cab, to admit boiler steam to the low-pressure cylinder, and permit the high-pressure cylinder to exhaust into the atmosphere at the same time. This was done precisely in the same manner by Mr. Baxter in 1870. No mention is made of an equalizing pressure valve for the low-pressure cylinder.

The English patent of Edwin Foden for a compound traction engine, July 23, 1885, claims:

"In compound engines, having either one or more high-pressure steam cylinders in combination with one or more low-pressure steam cylinders, the use of a three-way cock, or its equivalent, for the purpose of temporarily suspending the compound action of the high-pressure steam cylinder and the low-pressure cylinder, so as to cause each cylinder to receive its steam direct from the boiler, and to exhaust its own steam direct into the atmosphere, or independently, so that the low-pressure cylinder, does not then take the exhaust steam from the high-pressure steam cylinder, but becomes for the time being an additional high-pressure steam cylinder."

Mr. Foden's drawings do not show a reducing or relief valve, nor does he lay claim to such a device; but he prefers to provide the steam box of the low-pressure cylinder with one to reduce the pressure within.

The English patent of Richard C. Parsons, August 3, 1886, provides a valve which opens the high-pressure exhaust to the atmosphere. This valve is normally held close by a spring, but is opened by steam upon a piston connected with the valve, which piston is controlled by the engineer by means of a pipe and a cock.

Another drawing shows a second valve which admits live steam to the low-pressure cylinder and at the same time opens high pressure exhaust to the air. There is no mention of an equalizing pressure valve.

The English patent of Wm. Hornsby and Fred. J. Cribb, November 25, 1886, exhibits a slide valve, operated both ways only by the engineer from the cab, for admitting live steam to both high-pressure and low-pressure cylinders and opening the exhaust of the high-pressure cylinder to the atmosphere when starting.

The United States patent of Thomas W. Worsdell, dated April 5, 1887, following his English and French patents, says: "One of the cylinders takes steam direct from the boiler. When this steam is exhausted it passes through a superheating pipe to the low-pressure cylinder. After performing its function therein, the steam from the low-pressure cylinder is exhausted direct up the chimney."

"To render the engine efficient in starting, a starting valve is provided by which steam can be conveyed direct from the boiler to the low-pressure cylinder, and in order to prevent such steam filling the exhaust steam pipe of the high-pressure cylinder, and consequently the high-pressure cylinder itself there is provided a valve that I call the 'intercepting valve.' When closed this intercepting-valve will prevent the live steam getting back to the high-pressure piston. A flap-valve is preferred as it can be closed at will, and will always be thrown open by the steam itself when exhausting commences from the high-pressure cylinder. The starting-valve may be arranged to be opened by hand against a spring, so as when liberated to be closed in an automatic manner. The low-pressure cylinder is fitted with a relief valve at each end, to prevent the cylinder being charged at too high a pressure when steam is admitted direct from the boiler through the starting-valve."

No means are provided for running this engine continuously as a simple one, and no device shown or described for proportionally reducing the live steam pressure in the low-pressure cylinder.

The United States patent of August Von Borries, dated April 19, 1887, after seven foreign patents for the same invention, has for its object the construction of a two-cylinder compound locomotive, such that the connection between the cylinders can be cut off and both be worked at high-pressure when desired. An automatic valve is used for intercepting the high-pressure cylinder exhaust pipe and in the same movement of this valve, when it closes, a small live steam opening is made into the low-pressure cylinder steam chest. The moment this valve opens, by accumulated pressure in the high-pressure cylinder exhaust pipe, the live steam openings are closed and the engine goes at once into compound working.

There is no provision for continued simple running and no means for equalizing steam-pressure upon the two pistons.

The English patent of Halpin and Timmins, July 14, 1888, claims: "In a two-cylinder compound locomotive; a starting valve, consisting of a double seat valve loaded directly by a coil spring and allowing (on the engine being started), high-pressure steam from the boiler to pass directly into the low-pressure cylinder, until the back-pressure of the steam in the receiver and that of the spring, which act on the top area of the valve, exceed the pressure of the boiler steam, acting on the lesser area of the underside of the valve, in consequence of which the said valve drops back on its seat and then the engine works compound."

In Robert Lindner's United States patent, May 28, 1889, the remark is made, that: "It is necessary, in locomotives in starting the engine that steam of a reduced pressure direct from the boiler be admitted to the low-pressure cylinder, in order that the low-pressure cylinder should start the engine."

To accomplish this result, he provides a cock in a small branch pipe for admitting boiler steam to the high-pressure cylinder exhaust pipe, connecting the lever of this cock to the reverse lever and constructing the cock so that it shall admit steam only at the extremes of its stroke. He also forms small vent holes on the inner lips of the high-pressure cylinder slide valve, which in the middle of its travel, relieves the high-pressure piston from unequal strain, by opening both ends of the cylinder to the exhaust pipe for a moment, while the valve is passing. No device is mentioned for equalizing the steam pressure in both cylinders other than by wiredrawing it into the low-pressure cylinder.

The United States patent of J. Lewis, dated June 11, 1889, consists of four parallel cylinders, under the smoke-box, the steam to all of them is controlled by one rotating elastic valve, centrally located. One high-pressure and low-pressure cylinder on each side of locomotive is connected to one cross-head, with one connecting-rod to the crank.

One valve, controlled by engineer, for admitting boiler steam to both low-pressure cylinders at starting.

No mention is made of independent exhaust for the high-pressure cylinders at starting, and no allusion to, nor provisions for, equalizing the pressure of steam upon the pistons, when live steam is used in low-pressure cylinders.

The elastic valve will permit unequal compressions in the cylinders to escape.

The power of the high-pressure cylinder is necessarily weakened when live steam is admitted to the low-pressure steam chest.

The United States patent of Richard H. Lapage, dated July 8, 1890, following his English patent is for a three-cylinder compound locomotive, in which, however, the *two* low-pressure cylinders act as one, being connected to one cross-head and receiving the exhaust steam in the usual way from the one high-pressure cylinder.

The only object of duplicating the low-pressure cylinder is, the specification says, to avoid the danger of "fouling the loading gauge, existing platforms, tunnels, and the like." "By this means the use of a large overhanging low-pressure cylinder is obviated." About this, we have proven, there is no real concern, as there is room, by proper designing, for any *required* single low-pressure cylinder.

In this engine there is no independent exhaust way to the atmosphere for the high-pressure cylinder; no means of continuous single running and no suggestion even of devices for equalizing the steam pressures in the high- and low-pressure cylinders.

The United States patent of Albert J. Pitkin, dated April 14, 1891, covers an intercepting valve operated by "live steam to close it and shut by pressure of the steam in the low-pressure cylinder."

9th claim: "A valve controlling the admission of live steam to the low-pressure cylinder and automatic mechanism for positively opening said valve;" that is, it is actuated by the intercepting valve.

No mention is made of, nor drawings show, an automatic pressure-equalizing valve.

The United States patent of Francis W. Dean, September 22, 1891, covers an automatic intercepting valve working vertically.

"The construction insures the opening of the converting valve before the pressure of exhaust steam in the high-pressure exhaust passage accumulates above the receiver-pressure and thus relieves the high-pressure piston of the early back-pressure."

"The intercepting valve opens in advance of an accumulated back-pressure on the high-pressure cylinder to any desired degree."

No mention is made or drawing to show an automatic pressure reducing valve for low-pressure cylinder.

This patent proposes to admit live steam to the low-pressure cylinder at the same time live steam is admitted to the high-pressure cylinder to facilitate starting. This is done through the intervention of an intercepting valve and a converting valve, both of which are vertically opened and shut.

When boiler steam is admitted to the receiver by which to run the low-pressure cylinder as a simple engine, the intercepting valve closes, so as to prevent this steam from filling the exhaust pipe of the high-pressure cylinder which would reduce or destroy its power.

There is no separate exhaust pipe to the atmosphere shown or described, for the high-pressure cylinder.

There is not a word said about the necessity of, nor a contrivance for equalizing the total pressures of steam upon the two pistons, when both are working as simple engines.

(C) NOTES, DATA AND REFERENCES BEARING UPON AND RELATING TO THE USE OF STEAM IN COMPOUND LOCOMOTIVES AND OTHER STEAM ENGINES.

In the preparation of this report, your committee has extended its searches and has presented a wider range of subjects than is usual in such cases.

This procedure is desirable in view of the increasing interest taken in the compound system of locomotive construction.

The advisability of detailing the means which have been employed to adapt the two-cylinder compound steam engine to the popular two-cylinder type of locomotive, has been considered to be right and proper in this connection since this type out-numbers all others.

Experience with locomotives, everywhere, has shown the advantages of simplicity of construction in all the working parts; this committee, therefore, has dwelt at considerable length upon such details and methods, as have contributed to economy, without increasing the number of parts used for transmitting the power of the steam to the driving wheels.

The volume of railroad service having grown to such unprecedented magnitude, we feel that whoever contributes to it, or reduces the cost of its maintenance, confers a lasting benefit upon mankind.

There is no claim made by Mr. Batchellor for a two-cylinder compound locomotive by itself considered.

It is well known that the first two-cylinder compound engine was invented and built in England by Jonathan Hornblower, in the year 1776, and was patented by him in 1781, as stated above.

It is also on record that one John Nicholson, an English "engine driver," devised and run a two-cylinder compound locomotive on an English railway in the year 1850, since which time numerous patents have been granted for two-cylinder compound engines adapted to stationary and locomotive use, and with attachments for various purposes. These attachments differ according to the conception of their inventors, and the service to be rendered by their inventions.

The question of the objectionable width of two-cylinder compounds, due to the increased diameter of low-pressure cylinder is answered by the fact that numerous engines of this type are now running in this country and abroad. Builders of engines are now making two-cylinder compounds, even of the heaviest type, and officers of several of our roads who are responsible for their performance are having them made.

As to clearance width of locomotive, from the *Locomotive Engineer*, for November, 1891, p. 206, we take the following:

"The question of the application of the two-cylinder compound locomotive, such as used in heavy service for both passenger and freight traffic, is answered by the Schenectady Locomotive Works' people, who have already built a number of the two-cylinder type, and have designed a heavy compound consolidation engine of equal capacity to the 22 x 28 inch cylinders on the Union Pacific, which are believed to be the largest and most powerful locomotives at work in regular road service at the present day.

"The low-pressure cylinder is thirty-two-inch diameter, yet the extreme distance outside of cylinder does not exceed that of other two-cylinder compounds now running.

"The design demonstrates the fact that the popular two-cylinder type of compounding can be applied to the heaviest locomotive in road service at the present time."

We have found on inquiry, that every superintendent of motive-power, or master mechanic in this country, who recently has built a compound engine, or rebuilt a simple engine by changing to compound, has in every case used the two-cylinder type.

So for example, Mr. Lander, of the old Colony, and Mr. Mitchell, of the Lehigh Valley, each is building a Dean. Mr. Stevens, of the Lake Shore, has had the Brooks Locomotive Works to build a two-cylinder engine; the C. B. & Q. has built one, and are now building two more of this two-cylinder type. In addition to these the Southern Pacific and the Atchison, Topeka and Santa Fé have done the same.

If there was any serious objection to this type of engine, due to its greater breadth, it is fair to believe these men would not order them built.

The Rhode Island Locomotive Works say: "In regard to the clearance width of the two-cylinder type of compounds there is no trouble whatever in going as high as a thirty-one inch diameter for the low-pressure cylinder, which is equal to about two and one-half times the area of the twenty-inch high-pressure cylinder. This proportion we consider is near right as it is possible to get, and we think that by taking a little pains in the designing, we could get even a larger cylinder than thirty-one inches, but have had no reason to look into the matter any further than this, as the twenty-inch cylinder for the high pressure is as large as anything that we have built on our largest consolidation engines, so that we do not think there is any ground for complaint on this score."

A contributor to the *Railroad Gazette,* for August 21, 1891, p. 575, says of two-cylinder compounds, in answer to the main objection, that "the cylinder ratio could not be made large enough, and room still be found for the cylinders within the permissible width of the locomotive." He not only proposes to offset the centre of the low-pressure cylinder to a point within the centre of its application on the crank pin, which, however, is proven unnecessary by references to replies given herein, but further asks, why not increase the diameter of the high-pressure cylinder and expand the steam more in that which would also help the engine in starting?"

"It is being generally conceded that the difficulty with the two-cylinder engine (he refers to certain existing types) is that after the first exhaust of the high-pressure cylinder, when it should be exerting a comparatively high-pressure on the crank pin, it is not doing so, because of the back pressure in the receiver, and when working compound the two-cylinder locomotive has not as much average total pressure on the piston as the simple engine which it was built to replace."

"This has resulted from following an empirical rule; that is, to make the high-pressure cylinder *one inch larger in diameter* than the cylinder of the simple engine of equal power; this is wrong."

"The two cylinder is really the simplest and most desirable type of compound locomotive."

Mr. Thomas Urquhart, *Proc. Inst. M. E.*, London, 1890, p. 60, says: "The results of the author's experience are such as to leave no doubt in his own mind that compound locomotives are the engines of the future in all countries. "What is really wanted, is to mature a thoroughly efficient *two-cylinder compound with moving parts as light as possible, and well balanced.*"

It is not worth while to consider the objection to weakened draft in the chimney by reason of diminished exhaust pressure and reduced number of exhausts, because all the compounds are running satisfactorily, with good steaming qualities.

In Mr. W. Fletcher's work on *Steam Locomotion on Common Roads,* London, 1891, we find the following in reference to the Messrs. Fowler's recent type of compound road locomotive: "By the use of a low-pressure cylinder working in conjunction with a high-pressure cylinder, the greatest possible amount of expansion is obtained, and almost all the power in the steam is used before it is discharged into the atmosphere, the pressure of the exhaust steam being only eight pounds, which is just sufficient to create a draught necessary for the combustion of the fuel.

"These engines will do the same amount of work with thirty per cent. less fuel and water than the ordinary engines in every-day use. In consequence of the steam passing from these engines into the atmosphere at the low-pressure of eight pounds, the noise caused by the exhaust and all dangers from sparks are avoided." The road locomotives of other builders in England have performed equally as well.

We have all been taught by long existing practice to believe that a locomotive boiler will not make steam enough for the needs of the engine, without blowing all the exhaust steam from both cylinders at high-pressure tension into the stack, and that any reduction of its strength would materially lessen the generation of steam. See Samuel's continuous expansion engine for proof of the existence of this belief prior to the year 1852, where part of the high-pressure exhaust steam and all from the low-pressure cylinder went for blast.

From Mr. J. Samuel's supplementary paper on his continuous expansion steam engine, we quote:

"As far as they went, however, they showed that the blast could be reduced without impairing the efficiency of the engine. In a goods engine of the largest size, on the Eastern counties, the valves were altered, but the cylinders were retained both of the same size, and the result was a saving of twelve pounds of coke per mile. In a passenger engine, the low-pressure cylinder was made double the area of the high-pressure one, and it was never found short of steam, though running with express trains of considerable weight for a month's regular work."

In M. Mallet's two-cylinder compounds, three of which were in service prior to May, 1878, employed on local traffic and at times running twenty-five miles per hour. "The draught was ample, so that the boilers in spite of small dimensions supplied the wants of the engine abundantly."

From the above statements, it would appear useless to consider this objection, because all the engines fitted with low-pressure blast are now running satisfactorily in this particular, and we may safely add the remark here that, as the Rhode Island compound can be run as a simple engine, at any time and for any length of time as a simple engine, with the full blast efficiency, due to simple running, there need not be any lack of rapid steam generation for want of known means for doing it.

Furthermore, there is less steam to be made if compounding saves some of it, and in any case, *all that is made goes through the stack.*

To answer the question as to the value of superheating the exhaust steam on its way to the low-pressure cylinder as patented by Hudson, reference is made to the results of experiments, conducted by the C. B. & Q.

R. R. Co., who concluded that the cost of maintenance was more than the advantages gained.

This has nothing to do, however, with extending the pipes through the smoke-box, which is the most direct course, has many constructive advantages and keeps them in a closed chamber heated to from 400° to 1,000° of temperature, which is, perhaps, the cheapest method of clothing them.

Mr. T. Moy (in *London Mech. Mag.*, for August, 1863), proposes to increase the efficiency of the heating surface of steam boilers, " by increasing the *surface in contact with the water*, without a further increase of the absorbent surface." He further says: " It is pretty generally known that flanges cast on air-warming apparatus, greatly increased the effect of such apparatus, the cause being that a greater surface of heated metal is in contact with the air." His plan is to form flanges on the outsides of the tubes. Whether this will be as effective when the heat is required to pass in a reverse direction, remains to be proven.

Mr. W. F. Dixon, of Paterson, N. J., in vol. xi, of *Trans. Amer. Mech.*, p. 870, on the " Efficiency of Locomotives," says: " The C. B. & Q. R. R. Co. between 1870 and 1874, went fully into the subject of superheating. In these experiments the front tube sheet of the engine was set back into the barrel of the boiler some distance from its normal position. In the space thus left was fitted a separate cylinder, filled with tubes, through which the products of combustion had to pass on their way to the atmosphere. The dry pipe entering this cylinder at the top, and the steam, after circulating among the tubes and becoming superheated in doing so, passed to the cylinders of the engine through pipes connected to the bottom of the superheater.

" The resulting economy was, however, more than offset by the expense of keeping up."

The most conclusive test of the compound locomotive is that which is made in road service by the rank and file of engine men, extending over considerable mileage, under the usual varied conditions of present practice and with conditions precisely alike.

Your committee is satisfied that this method of experiment and comparison has been fairly carried out in the cases before us.

This committee decided that we should make personal inspection of these locomotives; we take pleasure in repeating here the report upon their performance by one of its members:

" I was in New York on the 15th of March, 1892, and went over to Brooklyn to see the two-cylinder compound locomotive running on the Kings County Elevated Railroad. This engine was built by the Rhode Island Locomotive Works, and has been running several months. Went to the General Manager's office where was shown the performance sheets of their engines, and when the engine came along we got on and rode to the Ferry and then back to the terminus of the road (nearly eight miles) and then back again to the Ferry and then again up the steep grade (which is 180 feet per mile), where it acted as a helper for another engine.

" During this whole time the engine performed its duty to the *entire* *satisfaction* of everyone, showing no more trouble to operate than a simple engine.

"It *rides well*, and were it not for the *absence* of *noise*, *sparks* and *dust*, one would not know that he was on a compound engine. It is using a nozzle four inches in diameter and steams freely with the door partly open, nearly all of the time.

"There was not a single moment during all of my ride where any of the arrangements that are used to change from simple to compound showed any desire to give trouble, but on the contrary, they all responded promptly. The trip was a very pleasant and satisfactory one."

In estimating the economy of various types of compounds employed on different roads, care must be taken to note all the conditions of running, which may greatly affect the comparative result.

Engines built and used for yard work and suburban traffic which are well nigh all stops and starts, with very short spaces for compounding, must not be paralleled with express engines on long runs, with a clean sweep the whole distance for compound running.

We must beware of incongruous comparisons.

Mr. Angus Sinclair (Sec. Am. Rwy. Master Mechanics Assoc'n) says, in the *Trans. Soc. A. S. M. E.*, in article on the "Efficiency of Locomotives," by W. F. Dixon, 1890, "few engineers would allow themselves to be influenced by results which are not obtained in road service."

Your committee has considered the figures of coal saving from various authorities.

	Per Cent.
The first compound locomotive run in the year 1850 and Samuel's continuous expansion engine of 1852, saved in coke	20
Fowler's traction engines, English, saved	30
Foden's " " " "	21·10
Burrell's " " " "	30
Worthington's non-condensing steam pump	30
Worsdell's compound locomotive on English Railroad	18 to 25

Mr. Urquhart made various numerous experiments with petroleum fuel on five compound locomotives and an equal number of non-compounds during five summer months, which showed a saving in favor of the compounds of from 18·22 to 18·96 per cent. of such fuel. He also gained an economy of repairs on the passenger locomotives, equal to 49·2 per cent., and 28·8 per cent. on goods locomotives.

In reference to the valves used for reducing the pressure of steam when directly employed in the low-pressure cylinders, which are necessary to prevent over-pressure in the same, and equalize the steam action in both cylinders, your committee has not found any other in use that fulfils this important requirement to any noteworthy degree, like that one applied to the compound locomotives built by the Rhode Island Locomotive Works.

Many of the earlier and later methods of preventing an excess of live steam pressure in the low-pressure cylinder are by wire-drawing the steam through small pipes and drilled holes, which are opened and closed by the engineer or by automatic action of other valves, which control also the exhaust ways. Some prevent over-pressure by spring-loaded snifting, safety relief valves or slide-valves. Wasting the steam in the atmosphere within sight of the engineer, who will know by this escape that the cylinder has overmuch of steam, and can act accordingly.

Whatever kind is used, and the presence and absence of them will be noticed in the detail of the several devices and patents quoted.

Your committee does not believe that the mere suggestion of and use of a pipe with a connected cock or valve for admitting steam to *anywhere*, merits notice of novelty at our hands, nor does a spring loaded safety or relief valve for giving notice of over-pressure or danger claims special attention in an inquiry of this nature.

Your committee is fully persuaded that in the design and construction of a compound locomotive they should be made as simple as possible.

With the adoption of two cylinders the number of working parts will be reduced to a minimum; the steam ways and everything else appertaining to the employment of the steam in the machine will necessarily be the least intricate, and will in turn reduce first cost and maintenance.

Mr. Alexander Borodine states, in *Proc. Inst. M. E.*, London, 1886, p. 353: "Considering that the compound locomotive with which the experiments were carried out, involves scarcely any complication and that it costs about the same to build as the ordinary engines and that a decrease in consumption of fuel lessens the cost of boiler repairs and of providing feed water, etc., it may be concluded that there is an undoubted advantage in building locomotives on the compound system."

Your committee readily assents to this proposition. One of them, more than ten years ago, announced the fact that a compound land engine could be built for same money as the usual high-pressure non-condensing engines then built; the saving in boiler capacity and equipment fully pays for the necessary additions to the engine.

The economy of short steam passages by which "much waste of steam is avoided," and the exposure of "less surface is presented for atmospheric resistance and cooling—a very important consideration at high speeds," are points claimed by Mr. Joseph Lewis in his United States patent of June 11, 1889.

In the English patent (1889) of J. T. A. Mallet, mention is made of his preference for two cylinders "both for simplicity of construction and to avoid an excessive amount of cooling surface."

On the subject of the economy of steam expansion and loss of power by radiation, Mr. Robert Stephenson said "that in the 'Planet,' one of the early locomotives made in 1832, he had the cylinders carefully enclosed inside the smoke-box instead of being outside, and there was found to be a considerable increase of power effected by the plan. That was the first locomotive constructed with heated cylinders, and it appeared the principle ought never to have been deserted." (*Proc. Inst. M. E.*, 1852, p. 85.)

Mr. D. K. Clark found by the indicator diagrams "that a great condensation of the steam took place in exposed outside cylinders during the first part of the stroke, from the coldness of the cylinders, and a considerable amount of condensation also was caused even in protected cylinders, where they were not artificially heated by exposure to the hot air in the smoke-box, because the temperature of the mass of the metal in the cylinder remained about the mean temperature of the steam while expanding in the cylinder, which might be many degrees below the original temperature of the steam on entering from the boiler." (*Proc. Inst. M. E.*, 1852, p. 87.)

Mr. Cowper "thought there would not be found to be any loss by condensation in a well-protected cylinder; he had not found any to take place in the experiments that had been tried on expansion."

"With respect to Mr. Samuel's mode, lately patented, of working steam expansively to a degree contemplated at four to six times the initial volume, by exhausting from one cylinder into the other, it is plain that the necessary conditions for the economical employment of such an extent of expansion, demand a much better provision for the preservation of the steam than is to be found in the ordinary arrangements of outside cylinders. According to Mr. Samuel's designs, the cylinders are placed outside in the usual manner, without any expedient for preserving the temperature of the steam; and it is easy to understand that special means must be adopted for this object, to secure an economical promotion of expansive action to the extent peculiarly available by his system."

D. K. Clark, *Railway Machinery*, London, 1855, p. 84.

"Mr. Stephenson mentioned an experiment by Mr. Trevithick, in which he found that *one* bushel of coal burnt under the cylinder did as much duty as *five* bushels of coal burnt under the boiler, showing the economy of keeping the cylinder warm." (*Proc. Inst. M. E.*, 1852, p. 131.)

"The annular cylinder compound engine, worked with one slide valve, was originally proposed in 1837 by William Gilman, and it has for many years been used by a London engineering firm in the construction of engines to drive corn mills. But the writer (Fred. J. Bramwell, of London) believes that care has never been taken to steam-jacket the high-pressure cylinder, which has thus always been bathed in an atmosphere of the low-pressure steam; this the writer looks upon as the cause of considerable loss." (*Proc. Inst. M. E.*, 1872, p. 147.)

To the above observation we may add our own: If there is loss in expanding too far in one cylinder, by which the departing steam lowers the temperature of the cylinder below that of the incoming steam, then, indeed, a high-pressure cylinder entirely surrounded by low-pressure steam must be at a great disadvantage.

Watt's grand invention consisted in condensing in a separate vessel, his aim being to economize by keeping the cylinder "always as hot as the steam that entered it."

The transition of this happy thought to the kindred one of *expanding in a separate vessel* seems not to have been made, although embodied in Hornblower's invention. On this occasion Engineer Blunder sat upon the Wishing-gate.

This subject was earnestly studied and widely published by Craddock in the year 1840, and later on, who showed clearly the advantage of preventing high-pressure steam from coming in contact with the walls of a vessel from which low-pressure steam was escaping, and who also proved his theory to be true in practice by making a twin-cylinder engine which performed double work with the same amount of steam. As modern compound engine practice has made this matter as familiar to us as office words, we need no labored argument for demonstration of it; we can only wonder why a matter so simple was not taken advantage of long before.

We must understand once for all that expansive working of steam is not a *gain* but a *saving*. The want of a proper understanding of this difference may have been the cause of the diverse views which have been held upon this subject by prominent engineers.

Economy goes with the expansion of steam, and with least steam waste which are secured by proper proportioning of the cylinders to the work to be done, and by efficient clothing of the exposed steam chambers.

There is no reason for useless loss of steam on its way to work, when there are well-known methods of saving it.

Experiments prove that a well felted boiler will save twenty-five per cent. of fuel over an exposed one; even an open door sensibly affects the running of a stationary engine; then why are not locomotive cylinders seriously affected when the storm door is always wide open?

Proofs are already abundant that economy in the use of steam runs in the line of continued expansion in more vessels than one; we were told this just 116 years ago, and we are slow at learning the lesson and putting it in practice.

About the same time Cornish men told us that best clothing meant increased saving of steam.

It has always seemed strange that a weather-chilled railroad man never applies the same reasoning to his exposed steam cylinders that he promptly does to himself, the object being the same in each case—the retaining of heat.

The hydraulic engineer soon finds out that he must avoid sudden contractions and enlargements and sharp turns in the water-ways of his constructions.

All this speaks plainly to the engineer: Save your steam when you have made it against loss due to radiation, and spare it from needless resistances while passing from the generating vessel to the point of application.

Of all things provide that your steam shall act quickly, and this is effected most perfectly by the least number of parts and ways through which it is to flow.

In order that the points of these statements may be clinched, as applied to the subject before us, we repeat Watt's golden rule: "The supreme excellence of machinery is its simplicity." We further quote from one of our best English authorities on steam and on the machines in which it is employed:

"There is a peculiarity in the double-cylinder engine, in its requiring a pipe or passage of some kind, through which the steam must travel, from one end of the small cylinder to the opposite end of the large one; and this passage should evidently be as small in content as possible, consistently with allowing the free passage of the steam."

"When the communication is opened at the end of the stroke, the steam, passing from the small cylinder, has to expand and fill the passage before it enters the large cylinder; and if the passage be large, the steam must necessarily suffer a reduction of pressure in so doing, which must seriously diminish its effective action on the large piston during the future stroke, and so cause much loss."

"In some engines, the author found this loss so great as to waste nearly half the power of the engine; and even in the best that were examined, such a considerable percentage of loss occurred, as almost to neutralize the expansion altogether."

"Much attention was therefore given to this point in designing the new engines; and it was found essential to the success of the engines that some arrangement of valves should be adopted which should satisfy the following conditions:

(1) That they should be of the simplest possible character and free from liability to derangement.

(2) That they should admit of the steam being cut off from the small cylinder at such a point as might be necessary to secure the required regularity in the motive-power of the engine.

(3) That they should give the clearance spaces the smallest content possible, and in particular, should allow the passage between the two cylinders to be direct and unimpeded, and of no larger capacity than was absolutely necessary for the passage of the steam."

"It was further found conducive to economy that the passage between the two cylinders, should, if possible, be carefully protected from cooling." Wm. Pole, from *Newton's London Journal of Arts*, August, 1863.

The fact is well known to every locomotive engineer that the requirements of a locomotive differ wholly from those of a stationary engine.

The conditions vary continually.

When starting a locomotive its greatest power is needed, this may also be needed to overcome occasional resistances at any time along the roadway. That locomotive, therefore, which is supplied with mechanism, at the will of the engineer, capable of running the engine at full power at any time and for any length of time, and as easily convertible into compound running, must take the precedence over every other.

For elevated railway, rapid transit service, such locomotives as the two-cylinder Rhode Island type is admirably adapted.

Their extreme cleanliness and quietness, easy riding and economy of oil commends them highly for service in cities.

Their economy in the use of fuel and water, combined with the lighter carriage of these requisites, and a more even distribution of the application of their power to this kind of service, which is conducted upon structural highways, possess many advantages.

The ease with which these engines are thrown into simple working, having full pulling power, as becomes necessary at certain times of the day, when the flood-tide of travel is all going one way, and as happens on many roadways, these extra heavy loads must be taken at full speed, up and over long and steep gradients, and when these are passed, a simple turn of the hand will change to compound running.

A compound locomotive, with multiple cylinders, is not built for the sole purpose of getting more power; the chief object to be gained is the saving of steam, which can be done in two cylinders, as commercially well as in any greater number on a locomotive.

In all cases, whether two or more cylinders are used, it is generally understood that in order to secure good results, the cylinders are proportioned to the weight on the driving wheels, and to the pressure of the steam.

We are more concerned here, however, with the appliances by which any type of compound locomotive may be made *universally applicable* to *any* road and to *any* service.

This invention is not simply ingenious, although it takes rank with any having high merit in that particular, but the merit we desire to report favorably upon, and give award to, is of such character as possesses commercial value.

A two-cylinder compound can be put to any simple engine, for less cost than any other type, and in doing so will replace and require the least number of working parts. The altering of existing simple engines into two-cylinder compounds, is thus made altogether feasible, and the building of new ones can be done at a cost very little over simple ones of same type and power.

The Rhode Island Locomotive Works improvements solve these problems perfectly. They furnish a locomotive that, for any time and service is at once simple or compound—an accomplished fact which your committee believes has not been done before in any country.

A great number of two-cylinder compounds, having the Worsdell von Borries type of valves and steam-ways, have been made, and are now running with good economical results.

If, therefore, the two-cylinder type of engine is so well favored, as those referred to, which are limited to certain kinds of traffic, adapted to the special construction of these engines, how much more will the same type be valued when it is suited to every service, by being perfectly interchangeable, with full range of performance, either as simple or compound.

Your committee recognizes the fact of greater value in accomplished results by the manufacture and completion for active service of any machine.

An inventor, who, after conception of his scheme, builds it, puts it into service and proves it to have commercial value, is entitled to advanced credit at our hands for having done more than merely invent and patent.

We make this statement here because we find on investigation that not one-half the number of compound locomotives, which have been patented and described have ever advanced beyond the patent record and not one-quarter of them are placed upon the roads in service. Many of us know by experience that some patented machines are not even well begun with the issue of the patent.

During that noted controversy upon the discovery of the expansion of steam in Watt's time, a writer said: "Of two discoverers of the same principle, that one should have the merit, who first makes it known to the public."

To this type of expression, may be justly added: A large need of praise and right-of-way belongs to the party who harnesses a discovery by whomsoever made and puts it under full control to do our bidding. Nor should the mere patented or other existence of any invention in one original form (which may yet be within experimental limits), forbid the use of its like conceived by another although in modified form, when the same has been adapted and carefully fitted to new working conditions. In this the last shall be first by merit.

"The conditions on which the expansive working of steam in locomotives may be carried out with efficiency and success were stated by Mr. D. K. Clark, as early as 1852, in *Proc. Inst. M. E.*, for that year and briefly are as follows:

(1) The condition is to perfectly protect the cylinders.

(2) The combination of a sufficiently high boiler pressure of steam, (say) 150 pounds per square inch, with suitable proportions of cylinder and driving wheel, to admit of highly expansive working consistent with the required duty of the engine.

(3) The cylinder should be arranged to have the shortest practicable steam-way, and the valves should be relieved of pressure.

From Mr. D. K. Clark's latest, most elegant and comprehensive work on *The Steam Engine*, London, 1890, vol. iv, p. 603, we make a few extracts, which, on perusal, will be found to emphasize much that we have already said upon the compound locomotive.

"M. Anatole Mallet had early prepared designs for compound locomotives, in which one of the cylinders was made larger than the other; and in the beginning of 1876, an order was given for three of them. They were four-coupled six-wheel tank-engines, with two outside cylinders, 9·45 inches and 15·75 inches in diameter, with a common stroke of 17·72 inches, having areas in the ratio of 1 to 2·78. The working pressure in the boiler was 150 pounds per square inch."

"The 'starting slide valve' was fixed on the smoke box, by means of which the steam from the first cylinder might, at starting, be exhausted direct into the atmosphere, while steam from the boiler was admitted direct into the second cylinder, sufficiently wire-drawn to avoid an excessive difference of power between the two cylinders. When the valve was shifted into the opposite position the steam from the first cylinder was exhausted to the second cylinder. The engines were first tried in July, 1876; they made steam in abundance, and worked with perfect steadiness."

See Mallet's paper "On the Compounding of Locomotive Engines," in the *Proc. Inst. Mech Engineers*, London, June, 1879, p. 328.

To M. Anatole Mallet belongs the credit of first realizing the necessity of equalizing the total pressure of the steam in each cylinder of a compound locomotive engine, especially in those of a large size.

In his paper he describes "a *self-acting reducing valve*, whereby the steam pressure admitted to the large cylinder when working direct is reduced so as never to exceed a certain limit bearing a constant proportion to the boiler pressure."

This valve consists of "a piston having a rod of large diameter, which passes out through a stuffing-box at the back end and has no external attachment." The piston acts as a stop-valve sliding over a port at the back end," which opens and *partially closes* before and after the admitted steam to the starting-valve chamber. This valve was not provided with any means whereby its motions would be controlled, and, therefore, was liable to breakage from violent slamming, which was proven to be the case on the first trials of those made, the record of which appears in his paper on this subject.

We find no reference of attempts to improve or continue the use of this type of valve.

"Mr. A. Borodine, Chief Engineer of the Southwestern Railway of Russia, made comparative trials of a compound passenger locomotive on the Mallet system and an ordinary locomotive. The engines were identical, except the cylinders; they were tried on a section ninety-seven and one-half miles long, in the month of May, 1881. The results of twelve double-trips show an economy of steam of from four to eight per cent.; and of fuel, of from fifteen to eighteen per cent." "In July, 1881, the two engines took goods trains exactly alike, one to each, one after the other, at speeds considerably lower than those of the passenger trains, showing an economy of thirty per cent. in the consumption of steam by the compound engine and of twenty per cent. of fuel." "Further, experiments with these engines showed an economy of fuel of twenty per cent., with 2·5 expansions of the steam and thirty-two per cent. with 4·8 expansions." See *Proc. Inst. M. E.*, London, 1886, p. 297.

Mr. Clark devotes one chapter to a discussion of the Von Borries outside cylinder compound locomotive, in which he concludes: "Compared with ordinary engines of like dimensions, working on the same lines and taking the same trains, the compound locomotives effect an economy of from 14·3 to twenty-one per cent. of fuel." See *Engineering*, April 30, 1886, p. 434.

In his next chapter Mr. Clark says: "Mr. T. W. Worsdell, in 1885, designed and constructed his first compound passenger locomotive for the Great Eastern Railway, in which two cylinders were employed, placed side by side, between the side plates. The cylinders are eighteen and twenty-six inches diameter, twenty-four inches stroke, working to the crank-axle in the usual manner; the capacity-ratio of the cylinders is 1 to 2·09. The engine fitted with Joy's valve-gear and steam could be turned on direct to the second cylinder when required for starting."

The performance May 21, 1886, showed "a reduction of thirteen per cent. on the ordinary consumption."

"In January and February, 1885, comparative trials of compound and ordinary passenger locomotives were made on the Northeastern Railway, which proved a saving by compound engine of twenty-one and one-half per cent."

"In the year 1886–87, the comparative consumption of coal, by compound and ordinary goods engines working heavy express trains, was for ten engines each, and making a total run of 186,000 miles, a saving of fourteen and one-half per cent."

"There are now (April, 1890), about 600 compound locomotives on the Worsdell and Von Borries system, of which there are 120 on the Northeastern Railway. The average results of twelve months' working of these 120 engines, compared with the non-compound engines on the railway, drawing the same trains, 150 tons weight, show an economy of twenty-two per cent. of coal."

Mr. Thomas Urquhart, on Railway in Southeast Russia, has ascertained an average economy of eighteen and one-half per cent. of petroleum refuse in the performance of twelve compound goods engines and three compound passenger engines, as against non-compound. The capacity of the receiver between the first and second cylinders, has been successively increased from equality to the volume of the first cylinder to 1·3 and 1·8 times, with marked advantage. The pressure in the second cylinder does not drop so fast with the larger receiver." See *Proc. Inst., M. E.* London, 1890.

The early state of the art shows that ordinary cocks and slide and other forms of valves operated by the engineer have been used for admitting steam to the low-pressure cylinder directly from the boiler for starting the engine, to be operated again by the engineer, changing the engine to compound running when the extra resistance is overcome, some having independent escape to the atmosphere for the high-pressure cylinder, and some have closed exhaust chambers.

The *advanced state of the art* exhibits the use of valves in the high-pressure cylinder exhaust pipe or receiver, which are worked by steam automatically or otherwise.

The greater number of these valves are opened automatically by the high-pressure cylinder exhaust steam when its accumulated pressure exceeds that of the admitted wire-drawn live steam to the low-pressure steam chest. These are called intercepting valves, and no means are provided for holding them shut for continued simple running.

Your committee plainly sees that any engine, exhausting into a closed chamber must weaken after the first revolution, and must gradually cease to have power if this process continues, and that this effect happens just at the time when the greatest power is needed; and again when this chamber gets relief, the engine at once ceases to be a simple engine, and goes into compound working. If the engine has not got under way by this time, it must balk and simple running be tried over again.

In the specification of F. W. Dean (U. S. Patent, Sept. 22, 1891) mention is made of the fact of accumulated pressure in the high-pressure exhaust passage, and the necessity of relieving the same. It is also stated: "The intercepting valve opens in advance of an accumulated back-pressure on the high-pressure cylinder," so it appears that some inventors recognize this fact of back-pressure where and when it is not wanted.

The *perfected state of the art* must exhibit a two-cylinder compound locomotive engine whose mechanism is simplest in form and number of working parts, and whose steam ways are most uniform in section and most direct in course from boiler to the point of application.

In so far as your committee has ascertained from every reliable source at its command, the mechanism devised by Mr. C. H. Batchellor practically fulfils this requirement.

In this engine we have all the necessary devices by which a locomotive may be run at any time and at any place on the road and for any length of time demanded by the service, as a simple engine; each cylinder doing exactly half the work, whatever that may be, and without waste of steam.

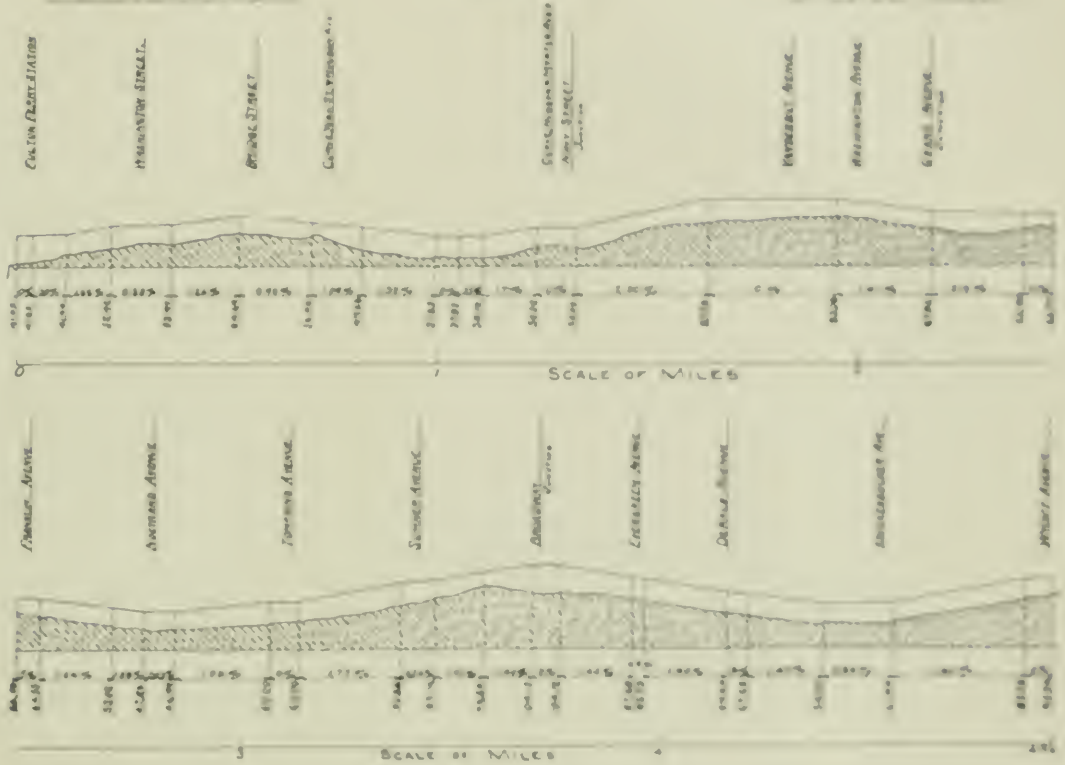
In addition to this, at the will of the engineer and at any time he chooses to exercise it, according to the conditions of running, he changes his engine into compound working, permitting it to operate thus as long as circumstances will warrant, and then he changes it back again at once into simple working. These changes are made as easily as the engineer turns his hand to open or close *one* valve, by a handy lever in his cab, and he does this when the engine is standing or running.

— PROFILE SKETCH —

RIDGEWOOD LINE
OF THE
UNION ELEVATED R R
FULTON FERRY STATION TO WYCOFF AVENUE
— BROOKLYN, N Y —

HORIZONTAL SCALE 1 IN = 500 FT

VERTICAL SCALE 1 IN = 50 FT



— PROFILE SKETCH —

BOSTON AND ALBANY R R
BETWEEN
SPRINGFIELD AND BOSTON

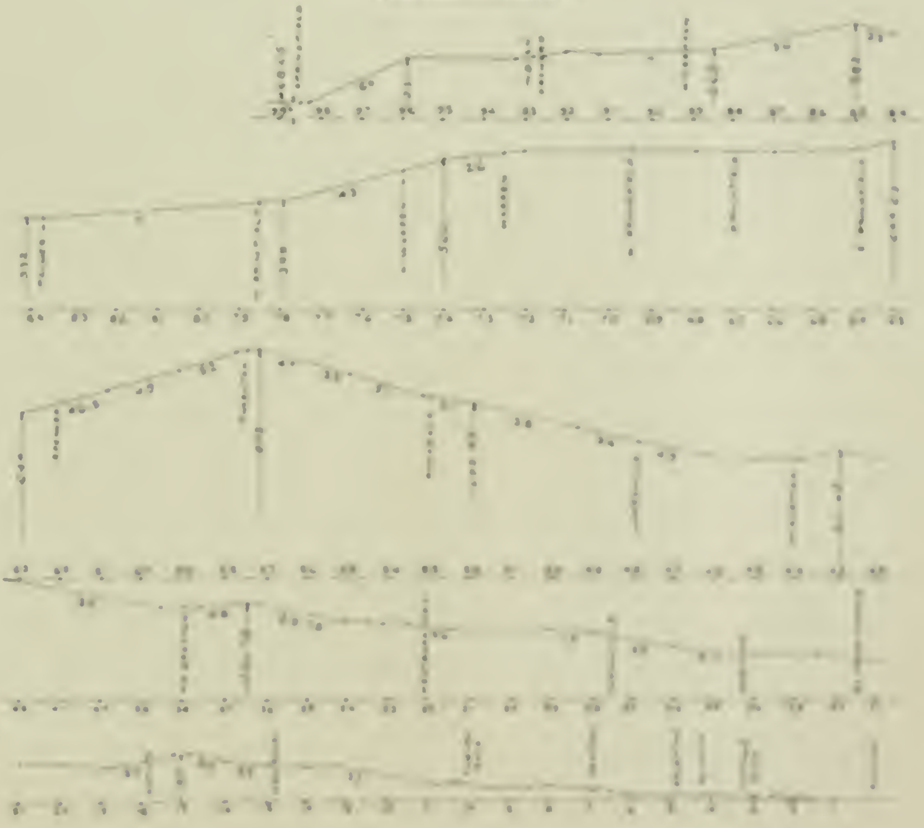


TABLE No. 4

LOCOMOTIVE DIMENSIONS.

ENGINE	COMPOUND 2600	SIMPLE N Y P & O 34	P & R 173 & 136
FUEL	SOFT COAL	SOFT COAL	SOFT COAL
CYLINDER - SIZES - R S	28 · 24"	18 · 24"	18" · 22
" " - L S	19 · 24"	18 · 24	18" · 22"
DRIVERS - DIAMETER	78	72	70
BOILER "	52"	52"	52"
" - FLUES - O D	2	2"	2"
" " - NUMBER	214	200	[illegible]
" " - LENGTH	10'-10"	11'-10½"	11'-0"
GRATE - STYLE	CAST IRON ROCKING	[illegible]	[illegible]
" - SIZE	[illegible]	[illegible]	[illegible]
" - AREA	[illegible]	[illegible]	[illegible]
HEATING SURFACE - TOTAL	[illegible]	[illegible]	[illegible]
" " - FIRE BOX	[illegible]	[illegible]	[illegible]
" " - FLUES	[illegible]	[illegible]	[illegible]
AREA RATIO - HEATING SURFACE TO GRATE	66.69	[illegible]	[illegible]
WEIGHTS - LOADED	[illegible]	[illegible]	[illegible]
" " - DRIVERS	[illegible]	[illegible]	[illegible]
" " - TRUCK	[illegible]	[illegible]	[illegible]

TABLE No 5-A

GENERAL DATA AND RESULTS OF TESTS
ON
NEW YORK, PROVIDENCE AND BOSTON R R

Schedule Running Time - Train No 23
Providence to New London - 64 Mls - 1 hr 40 mins

Schedule Running Time - Train No 42
New London to Providence - 1 hr 4[illegible] mins

		TRAIN No 23-WEST					TRAIN No 42-EAST					
Engine	Date-1891	Running Time Prov to N London (H M)	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty-Tons	Remarks	Running Time N London to Prov (H M)	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty-Tons	Remarks	Coal Weighed Out to Engine Pounds
NYP&B-34	3/16	1 47	35 95	448		Hot-Box Train left 2 mins late	1 40	38 55	448		Delayed by Train No [illegible] Train left 18 mins late	8617
	3/17	1 29	43 24	448		" " 17 " "	1 41	38 02	512		Delayed by Train No [illegible] Train left 10 mins late	9033
	3/18	1 40	38 55	448		" " on time	1 36	40 0	448		Delayed by Train No [illegible] Train left 6 mins late	4022
				Total 344	Total				Total 1408	Total	Weighed back	2134
											Total am't coal used during tests	24538
Compound-2600	3/19	1 40	38 55	448		Train left on time	1.35	40 5	448		[illegible]	8652
	3/20	1 40	38 55	448		" " " "	1 42	37 64	448		[illegible]	8236
	3/21	1 39	38 78	448		" " 1 min late	1 55	33 3	512		[illegible] Boston station stops [illegible]	4418
				Total 344	Total				Total 1408	Total	Weighed back	3000
											Total am't coal used during tests	8336

No of Regular Stops Train No 23 - 3
Regular Blowups at Time of Tests -
Elmwood - on acc't of excavations
Mystic Bridge
New London Bridge

No of Regular Stops Train No 42 - 3

TABLE No 5-B
SUMMARY

Engine Number	Total Car Mileage	Total Coal Consumption	Average Amount of Coal Used per Car Mile	Percentage of Coal Saved	Average Running Time Prov to N Lon	Average Running Time N Lon to Prov	Average Miles per Hour Prov to N Lon	Average Miles per Hour N Lon to Prov
34	2752	12 27 tons	8 91 lbs	——	1 hr - 38 6 mins	1 hr 39 mins	39 25	38 88
2600	2752	9 17 "	6 66 "	25 2 %	1 - 39 6 -	1 - 44 -	38 63	37 21

TABLE No 6-A
GENERAL DATA AND RESULTS OF TESTS
ON
NEW YORK, PROVIDENCE AND BOSTON R R

Schedule Running Time - Train No 39
Providence to New London 64 Mls - 1 hr 39 mins

Schedule Running Time - Train No 50
New London to Providence - 1 hr 39 mins

		TRAIN No 39-WEST					TRAIN No 50-EAST					
Engine	Date-1891	Running Time Prov to N London (H M)	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty-Tons	Remarks	Running Time N London to Prov (H M)	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty-Tons	Remarks	Coal Weighed Out to Engine Pounds
NYP&B-34	4/6	1 28	43 58	384		6 blow ups	1 [illegible]	45 77	384		4 blow ups	8816
	4/7	1 31	42 40	384		4 blow ups [illegible]	1 30½	43 10	384		6 blow ups 6 extra station stops	7123
	4/8	1 30½	43 10	384		3 blow ups	1 [illegible]	[illegible]	384		4 blow ups	4780
	4/9	1 28½	44 36	384		4 " "	1 27	44 82	384		3 " "	4706
	4/10	1 32½	42 20	384		6 " "	1 2[illegible]	43 83	384		3 " "	4478
	4/11	1 33½	41 72	384		6 " "	1 [illegible]	46 76	384		[illegible]	[illegible]
				Total 2304	Total				Total 2304	Total	Weighed back	[illegible]
											Total am't coal used during tests	[illegible]
Compound-2600	4/[illegible]	1 26	45 85	384		3 blow ups	1 26	45 36	384		6 blow ups	7767
	4/[illegible]	1 33	41 43	384		[illegible]	1 26½	45 10	384		6 " "	[illegible]
	4/[illegible]	1 2[illegible]	[illegible]	384		[illegible]	1 26½	45 [illegible]	384		6 " "	[illegible]
	4/[illegible]	1 32½	42 2[illegible]	384		3 blow ups	1 [illegible]	43 33	384		6 " "	4 [illegible]
	4/[illegible]	1 3[illegible]	43 1[illegible]	384		[illegible]	1 31	[illegible]	384		6 " "	4610
	4/[illegible]	1 32½	42 07	384		[illegible]	1 22½	47 27	384		6 " "	[illegible]
				Total 2304	Total				Total 2304	Total	Weighed back	[illegible]
											Total am't coal used during tests	[illegible]

No of Regular Stops Train No 39 - [illegible]

No of Regular Stops Train No 50 - [illegible]

TABLE No 6-B
SUMMARY

Engine Number	Total Car Mileage	Total Coal Consumption	Average Amount of Coal Used per Car Mile	Percentage of Coal Saved	Average Running Time Prov to N Lon	Average Running Time N Lon to Prov	Average Miles per Hour Prov to N Lon	Average Miles per Hour N Lon to Prov
34	4608	15 9[illegible] tons	6 9[illegible] lbs	——	1 hr [illegible] mins	1 hr 2[illegible] mins	42 84	44 7[illegible]
2600	4608	13 59 "	5 [illegible] "	[illegible] %	1 - 29[illegible] -	1 - 27 -	43 04	44 84

WATER ACCOUNT	Engine Number	Evaporated in Boiler	Used in Cylinders	Pounds Evaporated per Pound of Coal	Percentage of Water [illegible]
	34	25142 gallons	2506[illegible] gallons	[illegible] pounds	——
	2600	2381[illegible] "	[illegible] "	7 30 "	5 5 %

TABLE No 7-A

GENERAL DATA AND RESULTS OF TESTS ON BOSTON AND ALBANY R R

Schedule Running Time – Train No 19
Boston to Worcester – 44 miles – 60 mins
Worcester to Charlton – 13 5 – – 24 –
Charlton to Springfield – 4 – – 65 –
Boston to Springfield – 98 5 – – 2 hrs 29 mins

Schedule Running Time – Train No 18
Springfield to Charlton – 74 mins
Charlton to Worcester – 23 –
Worcester to Boston – 70 –
Springfield to Boston – 2 hrs [illegible]

		TRAIN No 19 – WEST									TRAIN No 18 – EAST									
Engine	Date-1891	Running Time in Minutes: Boston to Worcester	Worcester to Charlton	Charlton to Springfield	Actual Running Time Boston to Springfield H	M	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty – Tons	Causes of Delay	Running Time in Minutes: Springfield to Charlton	Charlton to Worcester	Worcester to Boston	Actual Running Time Springfield to Boston H	M	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty – Tons	Causes of Delay	[illegible]
Compound-2600	7/3	71	25	60	2	36	37 88	492 5	158 4	Freight at So Framingham	69	23	69	2	41	36 7	591	182 4	Hot box on car near Boston	3 5
	7/4	69	23	64	2	36	37 88	394	131		71	23	69	2	43	36 26	591	182 4	Switch engine at Boston	3 5
	7/5	69	24	63	2	36	37 88	394	131		74	23	68	2	45	35 8	654 8	203		3 5
	7/6	71	24	61	2	36	37 88	438	41 8	Signals blowup near Worcester	73	23	70	2	46	35 68	492 5	144 4		3 5
	7/7	71	25	70	2	40	35 68	394	131	Signal blowup at So Framingham Switchback to other main near Springfield	69	24	68	2	41	36 71	492 5	144 4	Worcester [illegible] signal at Tower 6	3
	7/8	69	25	62	2	36	37 88	394	131	Freight near Charlton	70	23	65	2	38	37 45	492 5	144 4		2 5
	7/9	72	23	62	2	37	37 59	394	131	Freight at Worcester	72	23	69	2	44	36 08	492 5	144 4		3
	7/10	71	25	60	2	36	37 88	394	131	Blowup at Worcester	73	23	70	2	46	35 68	492 5	144 4		2 5
	7/11	72	26	62	2	40	37 03	492 5	58 4	Signal at Worcester Torpedoes at Charlton	72	23	67	2	42	36 48	492 5	144 4		3
B. & A-136	6/24	70	26	63	2	39	37 17	394	131	Wait for orders at Worcester & Charlton	73	23	65	2	41	36 71	591	182 4		4
	6/25	70	22	64	2	36	37 88	394	131	Wait for orders at Worcester	72	23	69	2	44	36 08	492 5	144 4		3
	6/26	70	27	59	2	36	37 88	394	131	Blowups at Worcester	69	23	65	2	37	37 59	591	182 4		4
	6/27	72	25	61	2	38	37 45	492 5	58 4	Wait for orders at Worcester	71	23	70	2	44	36 08	492 5	144 4		3 5
	6/28	72	22	63	2	37	37 59	394	131	Signals at Worcester	74	23	70	2	47	35 43	492 5	144 4		4
	6/29	70	24	62	2	36	37 88	394	131	Blowup at Worcester	71	23	70	2	44	36 08	492 5	144 4		4 5
	6/30	69	22	63	2	34	38 47	394	131		73	23	70	2	46	35 68	492 5	144 4		3 5
	7/1	70	23	64	2	37	37 59	394	131	Wait for orders at Worcester	74	23	67	2	44	36 08	591	182 4		4
	7/2	69	23	64	2	36	37 88	394	131		72	23	64	2	44	36 08	492 5	144 4		3

No of Regular Stops Train 19 – 1

No of Regular Stops Train 18 – 2

TABLE No. 7-B
SUMMARY

Engine Number	Total Car Mileage	Total Coal Consumption	Average Am't of Coal Used per Car Mile	Percentage of Coal Saved	Average Running Time Bos to Spring	Average Running Time Spring to Bos	Average Miles per Hour Bos to Spring	Average Miles per Hour Spring to Bos.
2600	8613.5	29 Tons	6 73 Lbs	28 63 %	2 hrs 37¾ mins	2 hrs 39½ mins	37 51	36 32
136	8372 5	39 5 "	9 43 Lbs	——	2 " 36½ "	2 " 43½ "	37 75	36 2

TABLE No 8-A

GENERAL DATA AND RESULTS OF TESTS ON BOSTON AND ALBANY R R

Schedule Running Time – Train No 83
Boston to Worcester – 44 miles – 70 mins
Worcester to Charlton – 13 5 – – 24 –
Charlton to Springfield – 41 – – 64 –
Boston to Springfield – 98 5 – – 2 hrs [illegible] mins

Schedule Running Time – Train No 50
Springfield to Charlton 69 mins
Charlton to Worcester 22 –
Worcester to Boston – 69 –
Springfield to Boston [illegible]

		TRAIN No 83 – WEST									TRAIN No 50 – EAST									
Engine	Date-1891	Running Time in Minutes: Boston to Worcester	Worcester to Charlton	Charlton to Springfield	Actual Running Time Boston to Springfield H	M	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty – Tons	Causes of Delay	Running Time in Minutes: Springfield to Charlton	Charlton to Worcester	Worcester to Boston	Actual Running Time Springfield to Boston H	M	Average Speed in Miles per Hour	Car Mileage	Train Weight Empty – Tons	Causes of Delay	[illegible]
Compound-2600	7/14	77	24	57	2	38	37 47	635	140 5	Switchback to other main at So Fram	[illegible]	[illegible]	65	2	34	37 17	[illegible]	[illegible]	[illegible]	4
	7/15	70	23	65	2	38	37 45	541	180	Switchback to other main at Springfield	70	22	67	2	39	37 17	[illegible]	[illegible]	[illegible]	[illegible]
	7/16	70	25	62	2	37	37 59	541	180		69	22	68	2	39	37 17	[illegible]	[illegible]	[illegible]	3
	7/17	75	23	59	2	37	37 59	541	180	Blowup bet So Fram & Worcester	72	22	[illegible]	2	36	[illegible]	[illegible]	[illegible]	[illegible]	3
	7/18	71	24	62	2	37	37 59	541	180		70	22	64	2	36	[illegible]	710 5	[illegible]	[illegible]	3
	7/20	70	25	62	2	37	37 59	541	180		72	22	69	2	43	36 [illegible]	[illegible]	[illegible]	[illegible]	3 5
	7/21	73	24	61	2	38	37 46	541	180		71	22	66	2	39	37 17	[illegible]	[illegible]	[illegible]	[illegible]
B. & A-173	7/6	71	26	61	2	38	37 45	689 5	207 4		70	22	70	2	46	[illegible]	806	243 1		3
	7/7	71	25	61	2	37	37 59	541	180	[illegible]	[illegible]	22	67	2	[illegible]	[illegible]	[illegible]	[illegible]		4 5
	7/8	70	24	64	2	38	37 45	541	180		70	22	67	2	39	37 17	[illegible]	[illegible]		4
	7/9	70	24	64	2	38	37 45	541	180		71	20	[illegible]	2	38	[illegible]	[illegible]	[illegible]		4
	7/10	73	24	61	2	38	37 45	541	180		[illegible]	[illegible]	[illegible]	[illegible]	36	[illegible]	[illegible]	[illegible]		4
	7/11	72	23	61	2	36	37 88	541	180		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		4 5
	7/13	72	23	61	2	36	37 88	541	180		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		4 5

No of Regular Stops Train 83 – 1

No of Regular Stops Train 50 – [illegible]

TABLE No 8-B
SUMMARY

Engine Number	Total Car Mileage	Total Coal Consumption	Average Am't of Coal Used per Car Mile	Percentage of Coal Saved	Average Running Time Bos to Spring	Average Running Time Spring to Bos	Average Miles per Hour Bos to Spring	Average Miles per Hour Spring to Bos
2600	8665	13 5 Tons	5 48 Lbs	21 6 %	2 hrs 37 mins	2 hrs [illegible] mins	37 [illegible]	[illegible]
173	8716	30 5 "	6 99 "	——	2 " 37½ "	2 " [illegible] "	[illegible]	[illegible]

TABLE N° 1

LOCOMOTIVE DIMENSIONS.

TYPE	COMPOUND	SIMPLE
FUEL	ANTHRA COAL	ANTHRA COAL
CYLINDER-SIZES-R S	18" × 16	11 × 16"
" " -L S	11½ × 16"	11 × 16"
" -PORTS-STEAM-R S	1" × 17	⅞ × 8½"
" " " -L S	⅞" × 10"	⅞" × 8½"
" " -EXHAUST-R S	2" × 17"	1¼" × 8½"
" " " -L S	2" × 10"	1¼" × 8½"
" -CLEARANCE-R S	10 2 %	8 %
" " " -L S	11 %	8 %
STEAM PIPE FROM BOILER-R S	2" DIA	3" DIA
" " " " -L S	3½" "	3" "
PISTON ROD DIAMETER	2"	2"
DRIVERS-DIAMETER	42"	42"
" -REVOLUTIONS PER MILE	480	480
BOILER-DIAMETER	42"	42"
" -FLUES-O D	1½"	1½"

TYPE	COMPOUND	SIMPLE
BOILER-FLUES-NUMBER	124	124
" " -LENGTH	65⅞	68⅞
EXHAUST TIP DIAMETER	3"	3¼"
GRATE-STYLE	WATER GRATE	WATER GRATE
" -SIZE	54¾ × 41	54¾ × 41
" -AREA	15 6 SQ FT	15 6 SQ FT
HEATING SURFACES-TOTAL	289 46 "	289 46 "
" " -FIREBOX	45 46 "	45 46 "
" " -FLUES	244 "	244 "
AREA RATIO-HEATING SURFACE TO GRATE	18 5	18 5
STEAM CHEST VALVE-STYLE	BALANCED	BALANCED
" " " -FULL TRAVEL	5	5
" " " -LAP OUTSIDE	[illegible]	⅞
" " " -CLEARANCE	[illegible]	[illegible]
WEIGHT-LOADED	45850 LBS	45350 LBS
" " -ON DRIVERS	31534 "	31034 "
" " -ON TRUCK	14316 "	14316 "

TABLE N° 2

GENERAL DATA OF TESTS

Time Eng 62	Time Eng 58	Trips 62 & 58	Miles 62-58	No. of Cars	Car Miles 62-58	Running Time 62	Running Time 58	Coal Used 62	Coal Used 58	Water Used 62	Water Used 58	Weather	Condition of Engines 62	Condition of Engines 58	Remarks
6 10	6 13	1						1,190	440			[illegible]		[illegible]	
6.33	6.35 7.08	En to F.F. 2	5	4	24	35	30	1,005		760	471				
7.50	7.34 7.39	To Ridge 3	5	4	20	24	26								[illegible]
8.05 8.10	8.08 8.?	To F.F. 4	5	4	20	25	2?			3062	[illegible]				
[illegible] 8.45	8.40 8.44	To Ridge	5	4	20	22½	25								[illegible]
[illegible]	[illegible] 9.2?	To F.F. 4	5	4	20	23	25			2042	[illegible]				
[illegible]	[illegible]	To Ridge	5	3	15	22	24								
[illegible]	[illegible]	To F.F. 6	5	2	10	22	24		800	2237	[illegible]				
[illegible]	[illegible]	To Ridge	5	2	10	23½	22½								
[illegible]	[illegible]	To F.F.	5	2	10	23½	22½			1841	[illegible]				
[illegible]	[illegible]	To Ridge	5	2	10	27½	23								
[illegible]	[illegible]	To F.F.	5	2	10	24	21			[illegible]	[illegible]				
[illegible]	[illegible]	To Ridge	5	2	10	23	21								
[illegible]	[illegible]	To F.F.	5	2	10	24	23½	800		1818	[illegible]				
[illegible]	[illegible]	To Ridge	5	2	10	24	[illegible]								
[illegible]	[illegible]	To F.F.	5	2	10	23½	24		800	[illegible]	[illegible]				
[illegible]	[illegible]	To Ridge	5	2	10	23	24								
[illegible]	[illegible]	To F.F.	5	2	10	[illegible]	[illegible]	[illegible]		1870	[illegible]				
[illegible]	[illegible]	To Ridge	5	3	15	[illegible]	[illegible]								
[illegible]	[illegible]	To F.F.	5	3	15	21½	[illegible]	800		[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	To Ridge	5	4	20	25	26								
[illegible]	[illegible]	To F.F.	5	4	20	24	[illegible]	[illegible]		[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	To Ridge	5	4	20	2?	24								
[illegible]	[illegible]	To F.F.	5	3	15	24½	[illegible]	[illegible]		[illegible]	[illegible]				
[illegible]	[illegible]	To En. house	5	4	24	24½	[illegible]			[illegible]	[illegible]				
TOTALS		24	122		386			[illegible]							

RESULTS

Gain in Fuel Consumption [illegible]	[illegible]
[illegible] Lbs	[illegible]
[illegible] Lbs	[illegible] Lbs
Gain in Water [illegible] %	[illegible]
[illegible] %	[illegible]
[illegible] %	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	

TABLE No. 1

INDICATOR CARD RESULTS

No.	Initial Pressure	Revs per Minute	Notch and Cut-Off	Horse Power (HP) HP	LP	H.P. Ratio [illegible]	[illegible] HP Cut Off	HP Release	LP Cut Off	LP Release	Remarks
1	146	192	[illegible]	[illegible]	[illegible]	1.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	140	258		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	132	246	[illegible]	72.45	90.18	1.24	17.28	[illegible]	[illegible]	[illegible]	
48	133	246		76.56	84.37	1.17	18.46	[illegible]	[illegible]	[illegible]	
7	115	270		63.62	74.21	1.17	19.82	[illegible]	[illegible]	[illegible]	
51	140	270		84.57	106.8	1.26	17.88	[illegible]	[illegible]	[illegible]	
50	143	282		81.41	103.4	1.27	18.36	[illegible]	18.34	[illegible]	
8	138	294		88.85	110.9	1.2	19.43	19.24	18.48	[illegible]	
45	128	300		70.38	93.49	1.33	19.41	19.83	[illegible]	[illegible]	
36	141	324		91.53	[illegible]	1.27	18.96	18.98	[illegible]	[illegible]	
25	117	120		[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]
3	119	228		[illegible]	94.93	1.22	19.52	19.22	[illegible]	18.3	
37	131	258	[illegible]	94.90	[illegible]	1.20	[illegible]	[illegible]	[illegible]	[illegible]	
33	142	258		95.38	[illegible]	1.22	19.73	20.28	[illegible]	[illegible]	
52	144	276		110.1	[illegible]	1.19	18.82	[illegible]	[illegible]	[illegible]	
9	[illegible]	282		106.9	[illegible]	1.17	19.29	19.42	17.62	[illegible]	
4	114	300		93.51	[illegible]	1.22	20.51	[illegible]	[illegible]	[illegible]	
10	131	318		107.9	[illegible]	1.24	19.81	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	330		116.6	139.9	1.20	19.32	[illegible]	[illegible]	[illegible]	
19	149	180	[illegible]	102.1	109.2	1.02	[illegible]	[illegible]	[illegible]	[illegible]	
20	147	234		123.6	133.0	1.08	19.86	[illegible]	[illegible]	[illegible]	
11	138	276		127.1	142.1	1.12	21.08	[illegible]	[illegible]	[illegible]	
34	134	282		125.9	148.3	1.18	20.48	[illegible]	[illegible]	[illegible]	
12	130	306		127.6	140.5	1.10	[illegible]	[illegible]	[illegible]	[illegible]	
42	127	150		[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]
15	124	[illegible]	[illegible]	107.6	[illegible]	[illegible]	22.37	[illegible]	[illegible]	[illegible]	
43	[illegible]	228		[illegible]	116.3	1.07	22.23	[illegible]	[illegible]	[illegible]	
44	[illegible]	252		130.1	133.7	1.08	20.70	[illegible]	[illegible]	[illegible]	
21	141	270		[illegible]	[illegible]	1.02	[illegible]	[illegible]	[illegible]	[illegible]	
31	[illegible]	[illegible]	[illegible]	104.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
22	143	210		136.2	137.8	0.997	22.21	[illegible]	[illegible]	[illegible]	
23	128	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
1	136	[illegible]	[illegible]	74.07	88.77	[illegible]	22.50	22.73	[illegible]	[illegible]	
17	143	192		134.0	[illegible]	[illegible]	[illegible]	22.73	[illegible]	[illegible]	
33	[illegible]	222		[illegible]	[illegible]	[illegible]	22.30	[illegible]	[illegible]	[illegible]	
32	144	270		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
27	136	[illegible]	[illegible]	122.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
28	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

PLATE I

No. 11
U.E. R.R. ENG. No 58
Steam 163½ Rev 192
Scale 80
AV M.E.P {HP 33 16 / LP 17 40 Ref to HP 42 63
TOTAL H P 122 12
R I Loco W'ks 8/6 '90

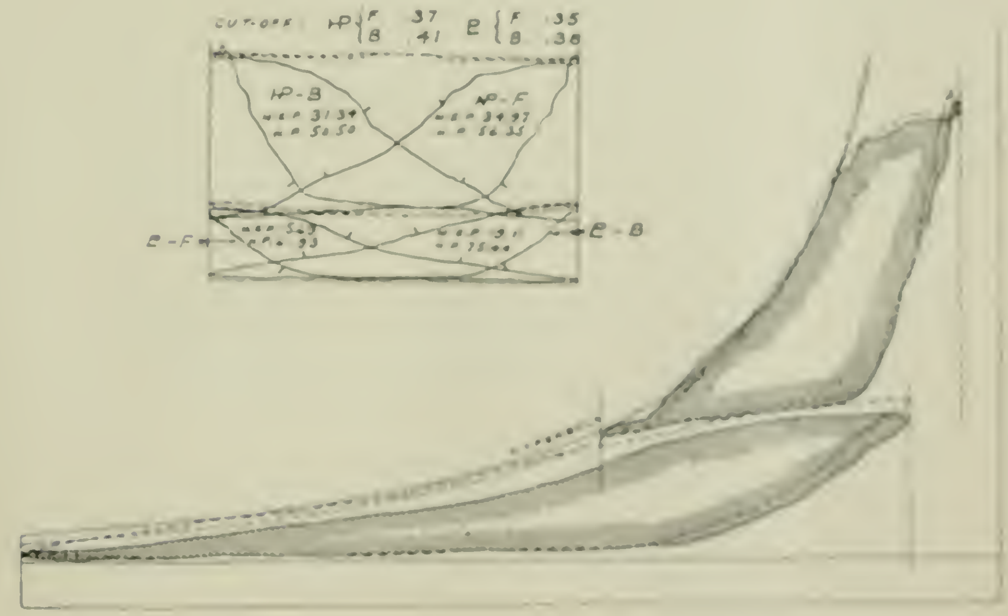


PLATE II

No 10.
U.E. R.R. ENG. No 58
Steam 163½ Rev 258
Scale 80
Av MEP {HP 30 84
LP 14 95 Ref to HP 36 63
TOTAL HP 146 11
R I Loco W'ks 9/13 '90

CUT-OFF: HP {F 37 B 41 LP {F 35 B 38

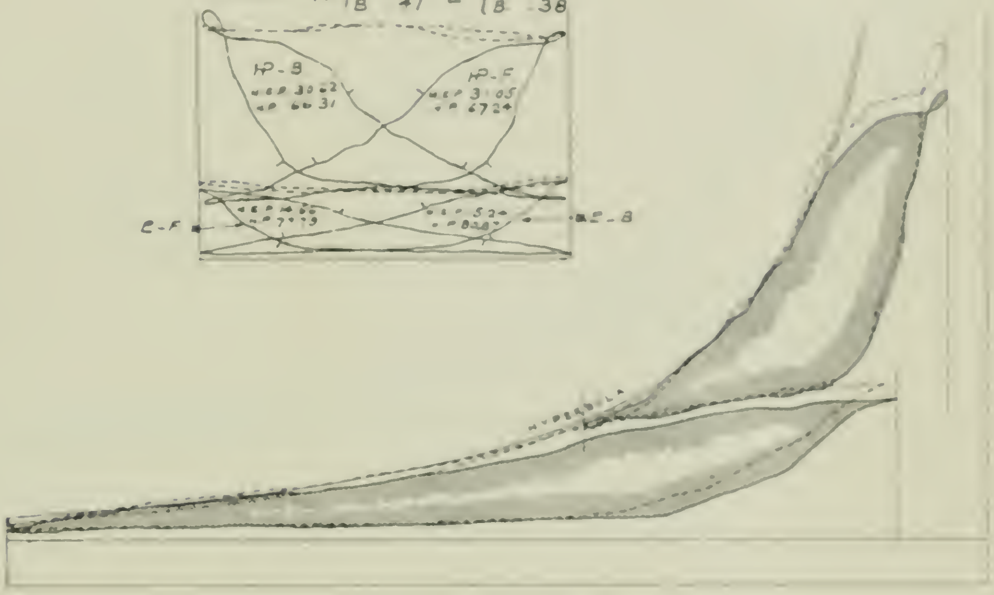


PLATE III

No 47.
U.E. R.R. ENG No 58.
Steam 151½ Rev 246
Notch 1 Scale 80.
Av MEP {HP 35 09
LP 17 83 Ref to HP 43 68
TOTAL HP 162 63
R I Loco Wks 9/30 '90

CUT-OFF: HP {F 45 B 47 LP {F 44 B 45

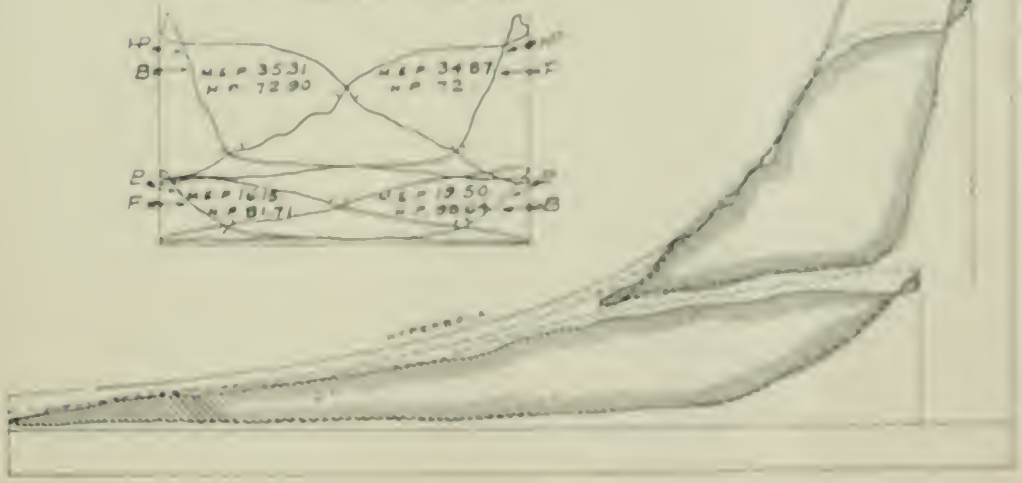


PLATE IV

No 51.

U.E.R.R. ENG No 52.

Steam 159. Rev 270
Notch 1. Scale 80

Av. M.E.P { HP 36.82
E 19.15 - Ref. to HP 46.92

TOTAL H P 190.9

R I Loco. W'ks 9/30 '90

CUT-OFF: HP { F 45, B 47 E { F .44, B 45

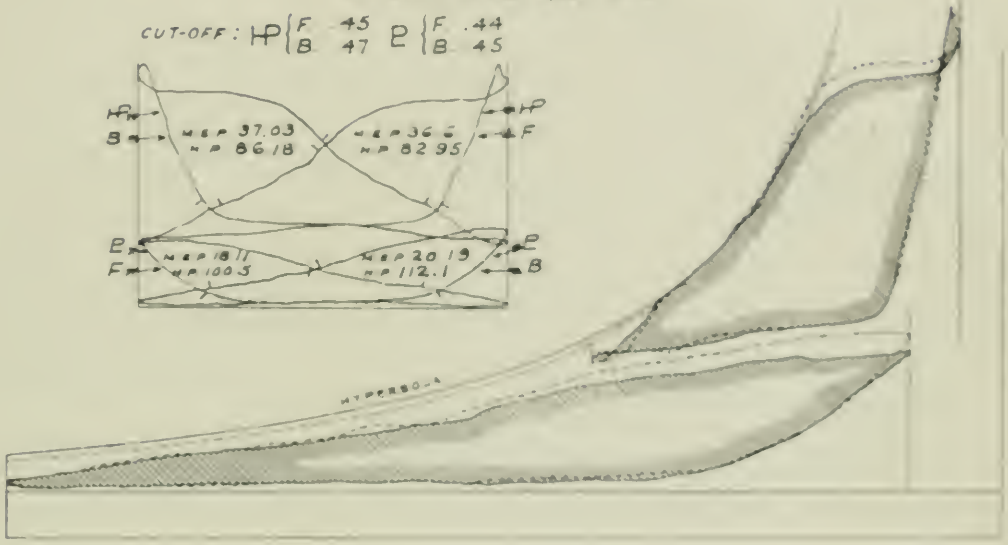


PLATE V

No 46.

U.E.R.R. ENG No 58.

Steam 155. Rev 324.
Notch 1. Scale 80

Av M E P { HP 33.66
E 17.46 Ref to HP 42.78

TOTAL H P 208.1

R I Loco W'ks 9/30 '90

CUT-OFF: HP { F 45, B 47 E { F 44, B 45

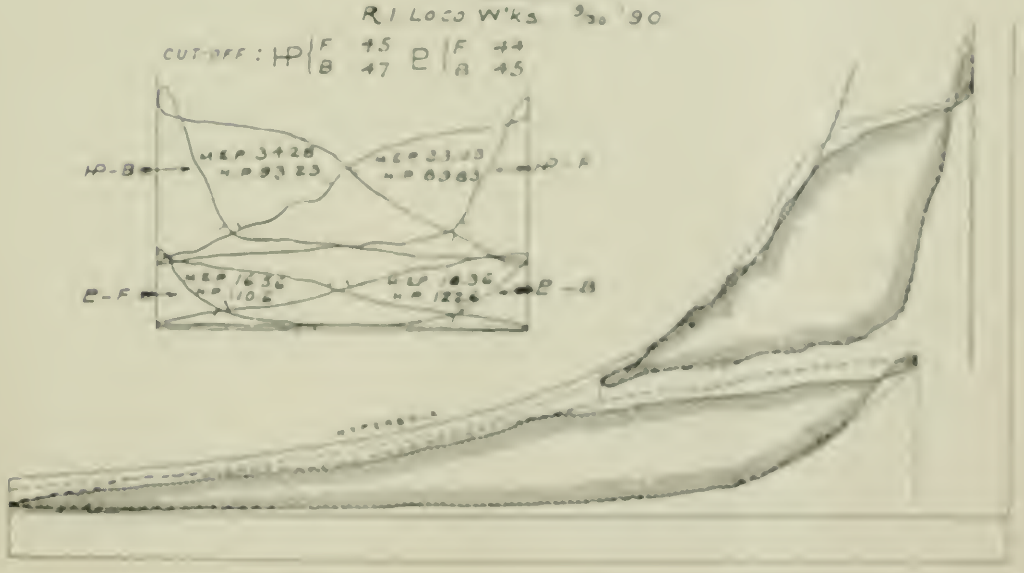


PLATE VI

No 3.

U.E R.R.   ENG. No 58.

Steam 139½   Rev 228
Notch 2   Scale 80

Av MEP { HP 40 80
LP 2025   Ref to HP 49 61
TOTAL H P 173

R I LOCO WKS 9/30 '90

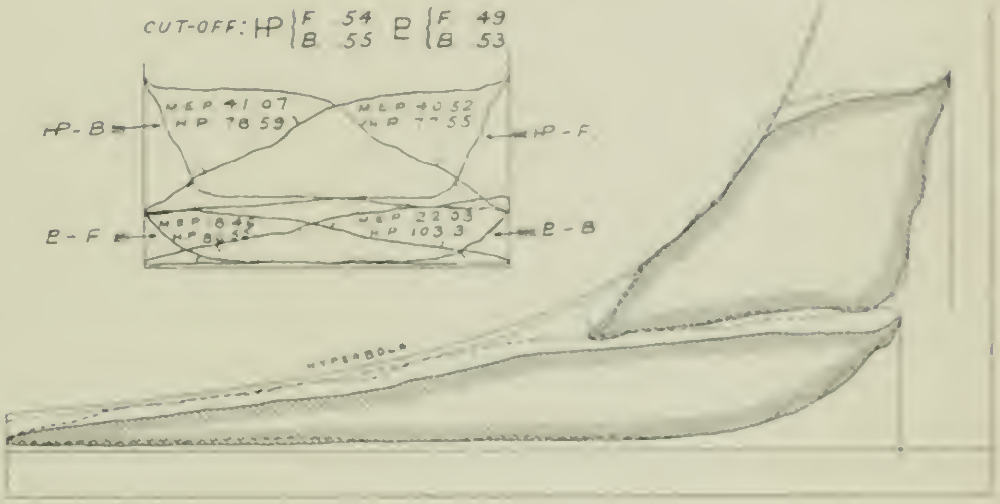


PLATE VII

No 52.

U.E. R.R.   ENG. No 58.

Steam 161   Rev 276
Notch 2   Scale 80

Av MEP { HP 47 78
LP 23 21   Ref to HP 56 86
TOTAL H P 242 4

R. I Loco W'ks 9/30 '90

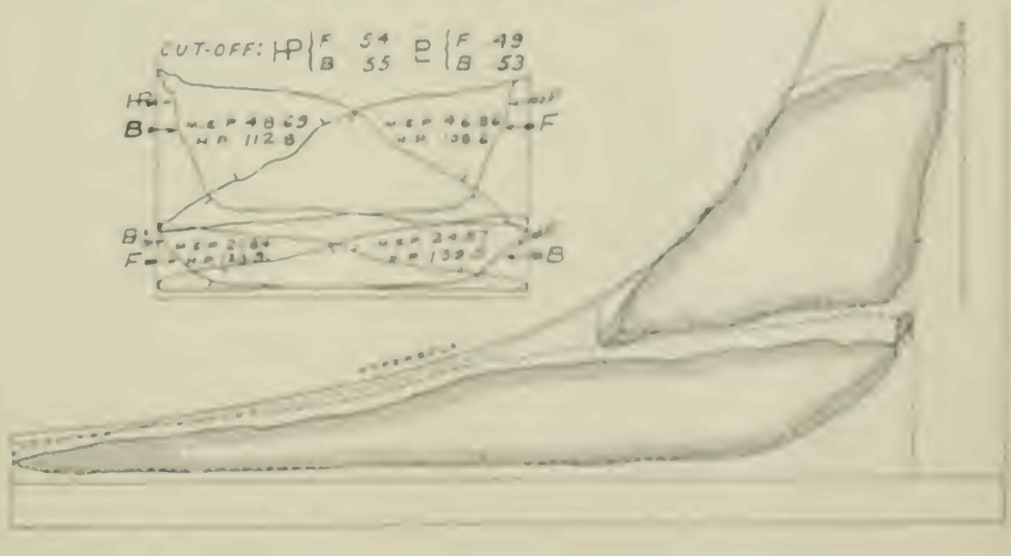


PLATE XIII

No. 35.

U.E. R.R. ENG. No. 58.

Steam 157 Rev 330

Notch 2 Scale 80

Av MEP { HP 42.07
LP 20.61 REF TO HP 50.49

TOTAL HP 256.5

R I Loco Wks 9/30 '90

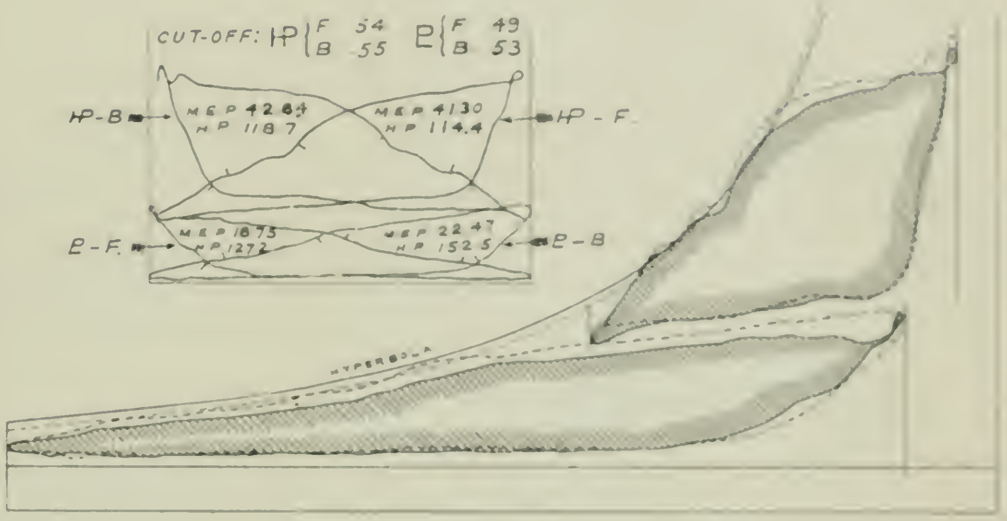


PLATE IX

No. 19.

U.E. R.R. ENG. No. 58

Steam 161 Rev 180

Notch 3. Scale 80

Av MEP { HP 70.87
LP 29.49 REF TO HP 72.25

TOTAL HP 216.3

R I Loco Wks 9/30 '90

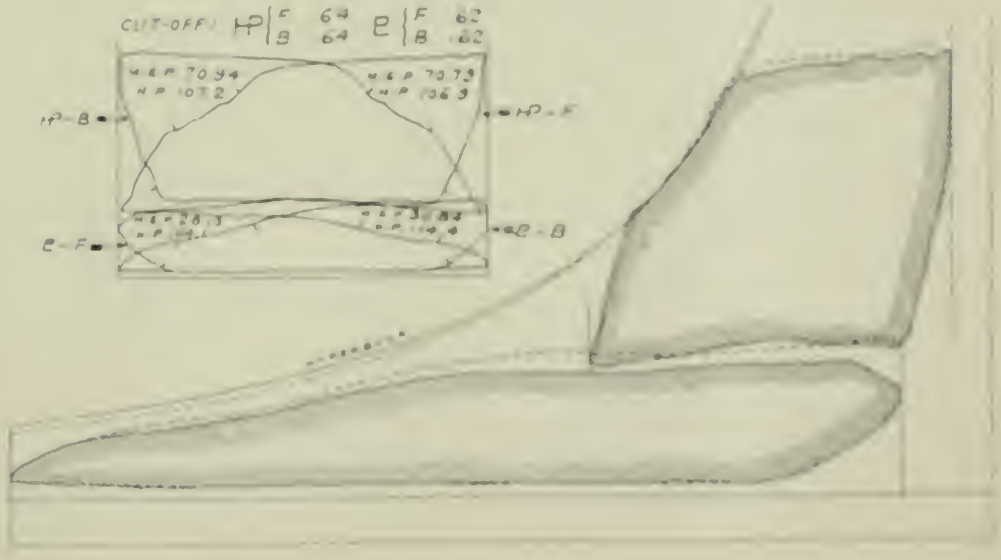


PLATE X

No. 34.

U.E.R.R. ENG. No 58.

Steam 148 Rev 282
Notch 3 Scale 80

Av M.E.P {HP 53 20
L 25 60 REF to HP 62 72
TOTAL H P 274 4

R I Loco Wks 9/30 90.

CUT-OFF. HP {F 64 B 64 L {F 62 B 62

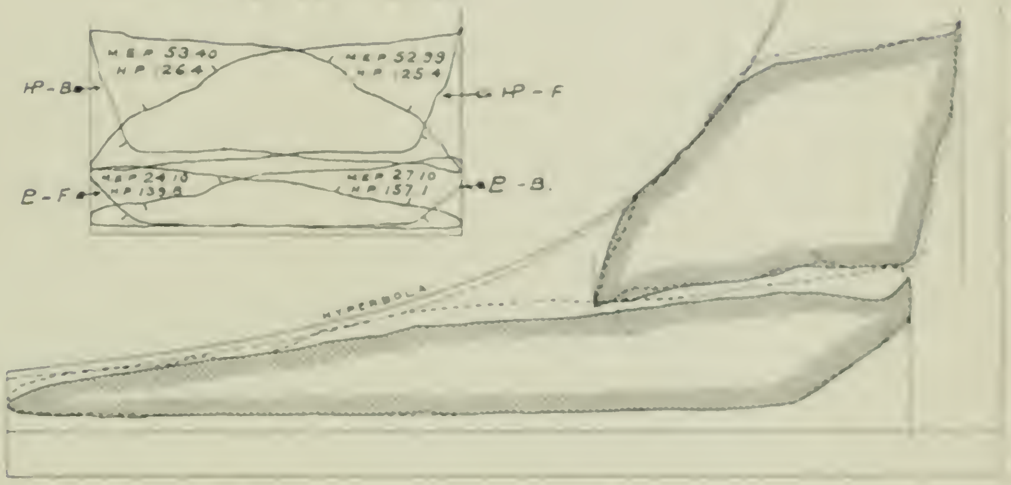


PLATE XI

No. 12.

U.E.R.R. ENG No. 58.

Steam 148½ Rev 306
Notch 3. Scale 80

Av MEP {HP 49 70
L 22 33 REF to HP 54 71
TOTAL H P 268 1

R. I Loco W'ks 9/30 '90

CUT-OFF. HP {F 64 B 64 L {F 62 B 62

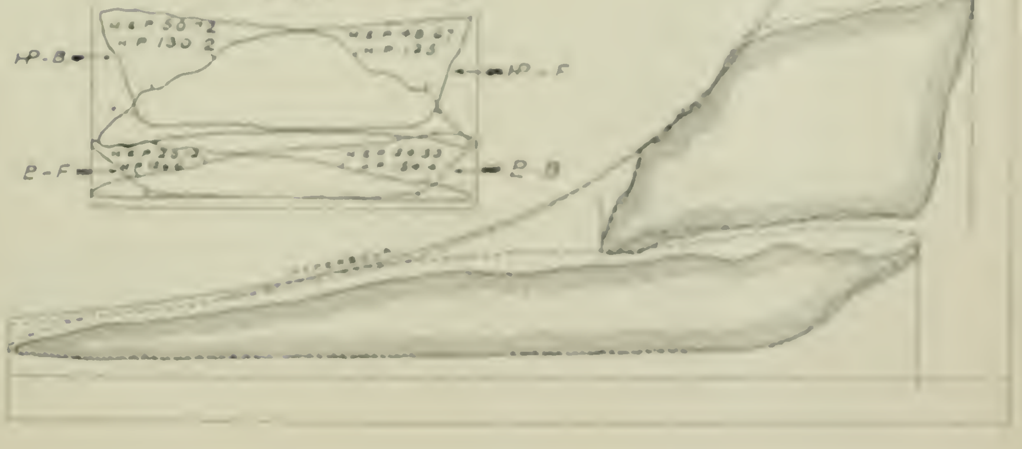


PLATE XII

No 15.

U.E R.R. ENG No 58

Steam 139½ Rev 210
Notch 4 Scale 80

Av M.E.P { HP 61.01
LP 25.06 Ref to HP 61.40
TOTAL H P 215.7

R I Loco W'ks $^{9}_{30}$ '90

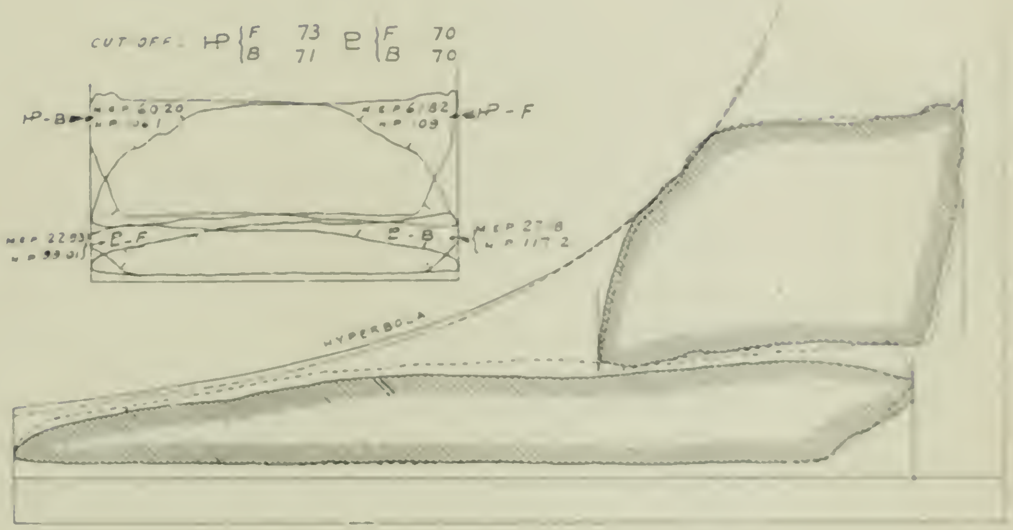


PLATE XIII

No 44.

U.E.R.R. ENG.No.58.

Steam 142½ Rev 252
Notch 4 Scale 80.

Av M.E.P { HP 61 51
LP 25 82 Ref to HP 63 26
TOTAL H P 263.8

R I Loco W'ks $^{9}_{30}$ '90

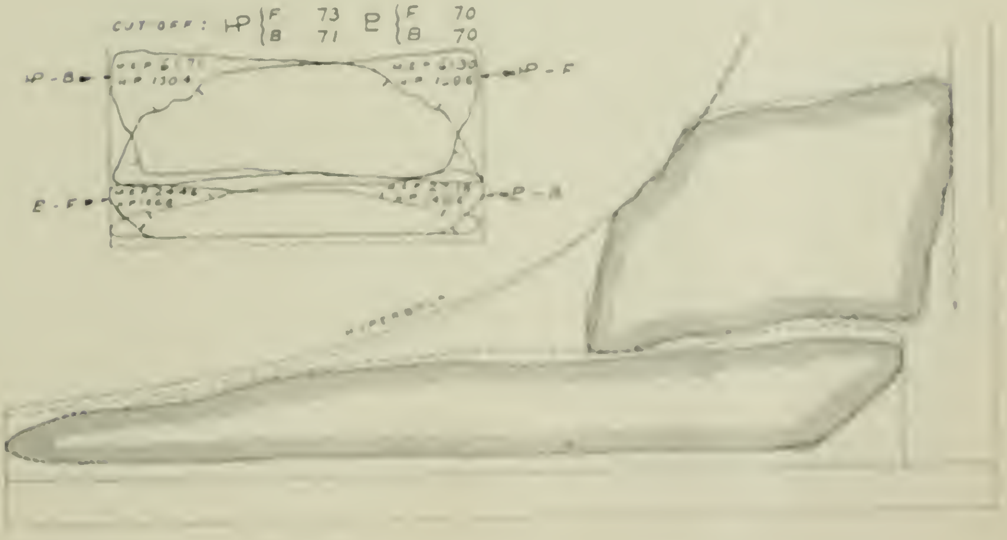


PLATE XIV

No 21.

U.E. R.R. ENG. No 58.

Steam 159 Rev 270
Notch 4. Scale 80
Av M.E.P {HP 66 02
{LP 27 50 Ref. to HP 67 37
TOTAL H.P 302 3
R I Loco W'ks 9/30 '90

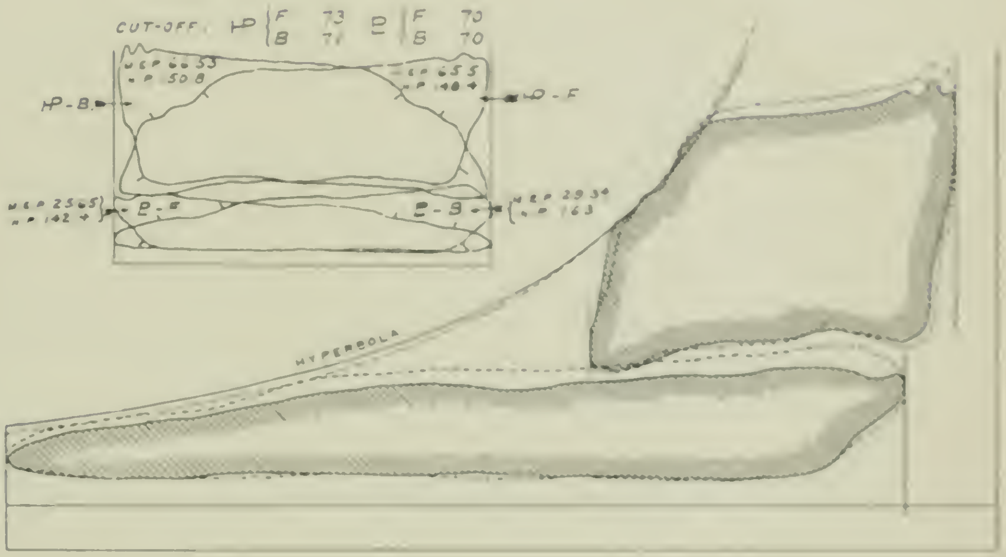


PLATE XV

No. 31.

U.E. R.R ENG. No 58.

Steam 145 Rev 168
Notch 5 Scale 80
Av. M.E.P {HP 74 01
{LP 34 13 Ref. to HP 83 64
TOTAL H.P 222 4
R I Loco. W'ks 9/30 '90

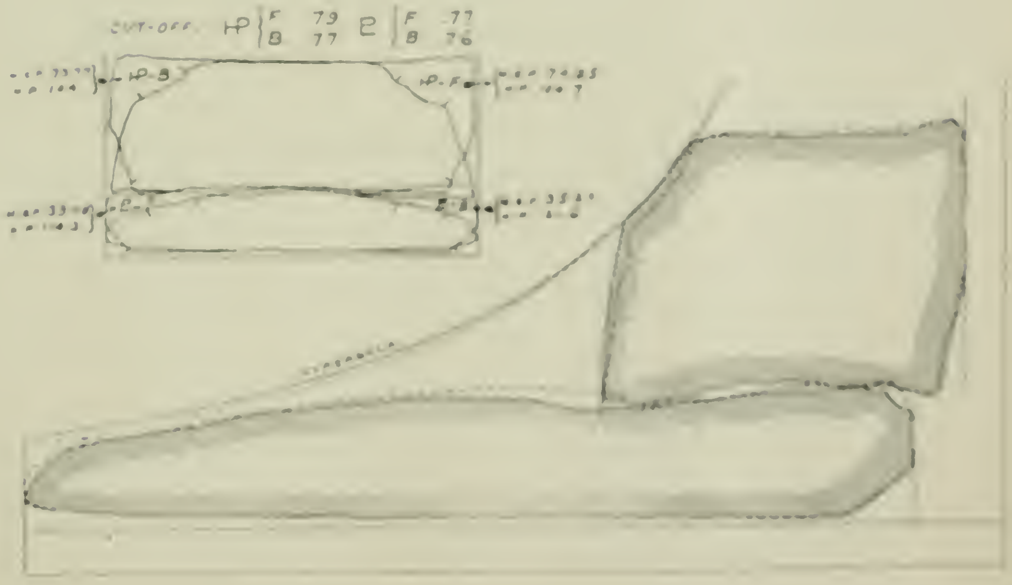


PLATE XVI

No. 22.

U.E. R.R. ENG. No 58.
Steam 156 Rev 210
Notch 5. Scale 80.
Av. M E P {HP 78.40 / E 31.92} Ref to HP 78 20
TOTAL H P 276
R I Loco W'ks 9/30 90

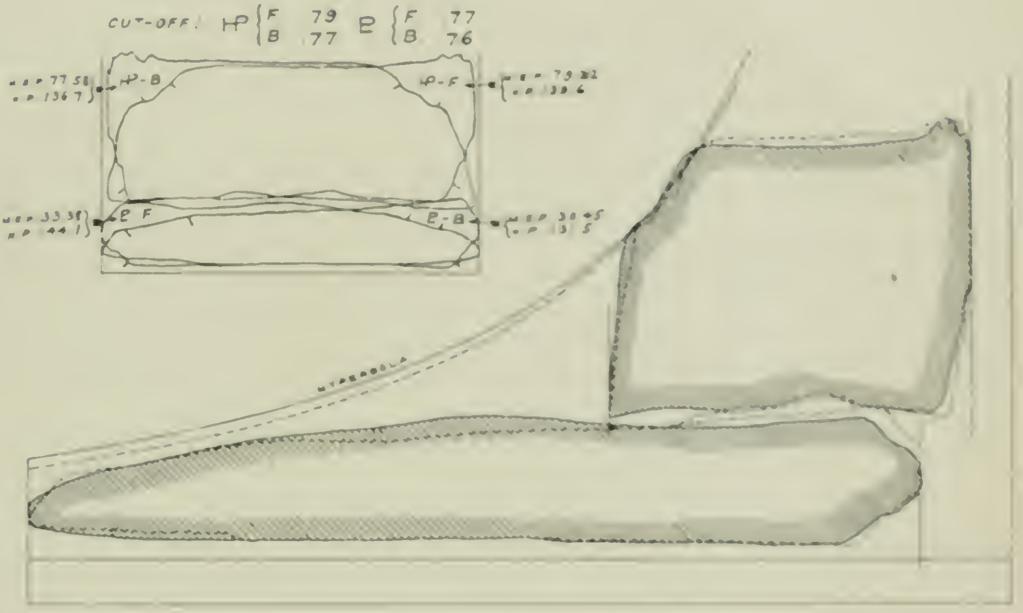


PLATE XVII

No 1.

U.E. R.R. ENG. No 58.
Steam 150 Rev. 100.
Notch 6 Scale 80.
Av M E P {HP 88 25 / E 33 45} Ref to HP 81 95
TOTAL H P 142 84
R I Loco W'ks 9/30 '90

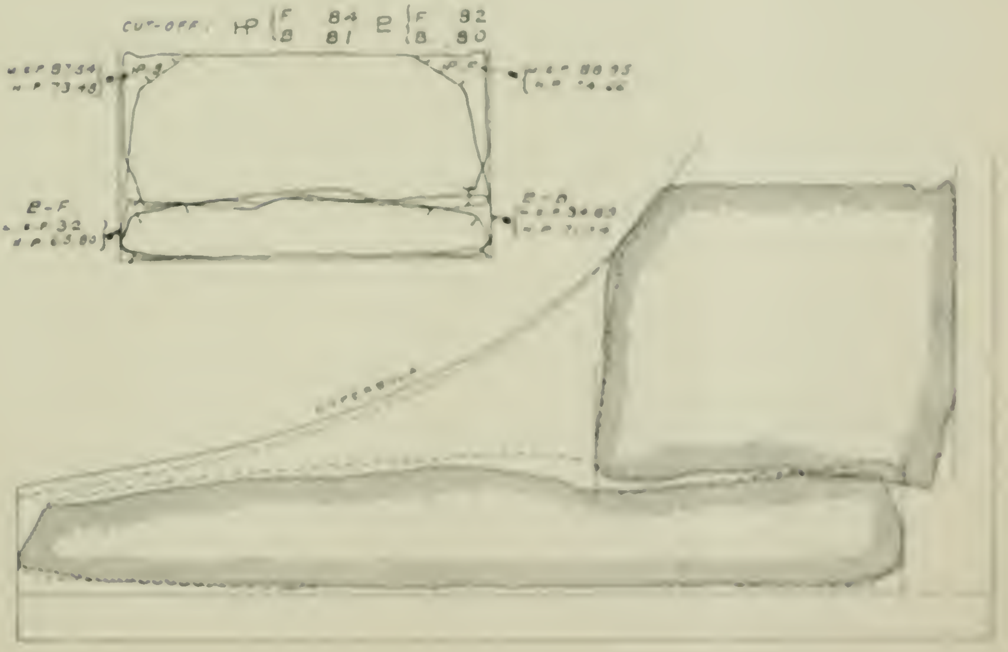


PLATE XVIII

No. 17.

UE RR ENG No 58
Steam 156 Rev 192
Notch 6 Scale 80
Av M E P { HP 84.15
E 33.59 Ref to HP 82.30
TOTAL H P 266.6
R I Loco W'ks 8/30 '90

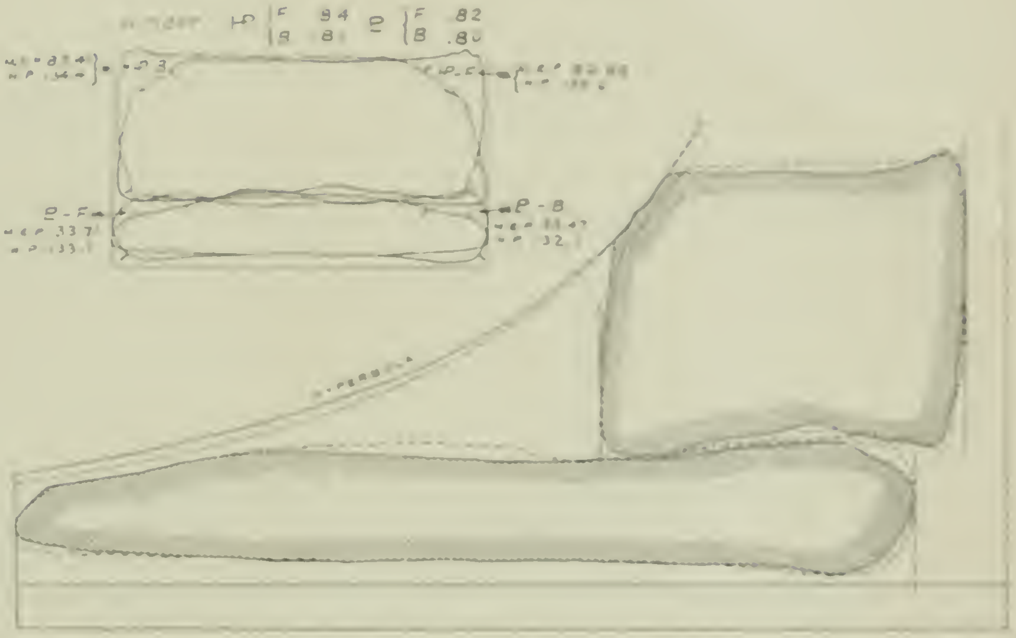


PLATE XIX

No. 32.

I E RR ENG No 58
Steam 161 Rev 270
Notch 6 Scale 80
Av M E P { HP 77.25
E 29.82 Ref to HP 73.06
TOTAL H P 340.6
R I Loco W'ks 8/30 '90

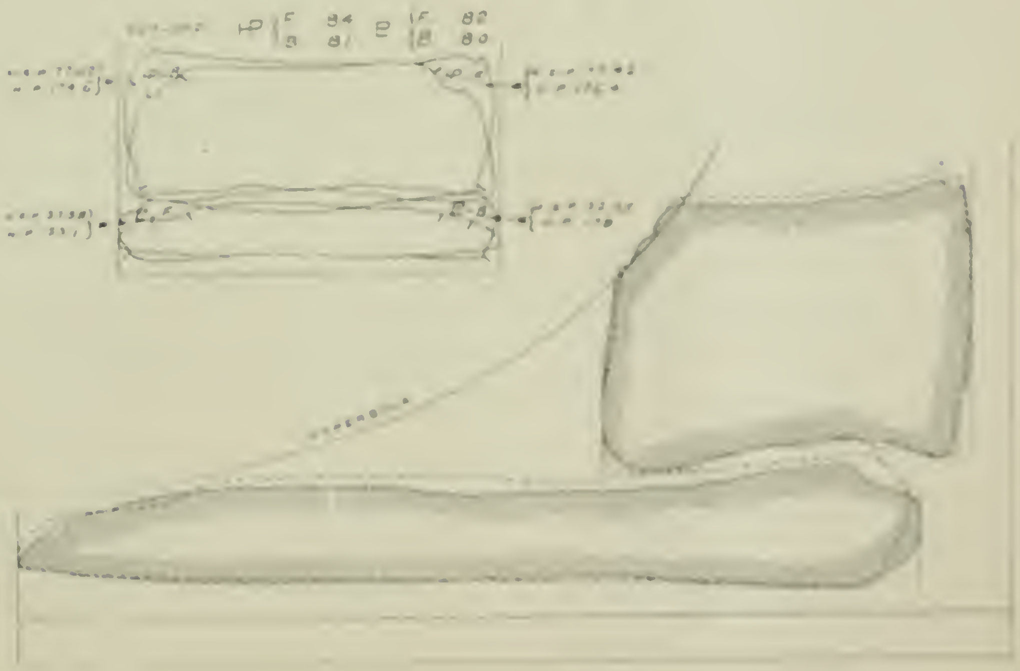


PLATE XX

No. 27
U.E. RR. ENG. No 58
Steam 145 Rev 180
Notch 7 Scale 80
AV M.E.P. {HP 82 77
E 30 84 Ref to HP 75 5[illegible]
TOTAL H.P. 236 [illegible]
R I Loco W'ks 9/30 90

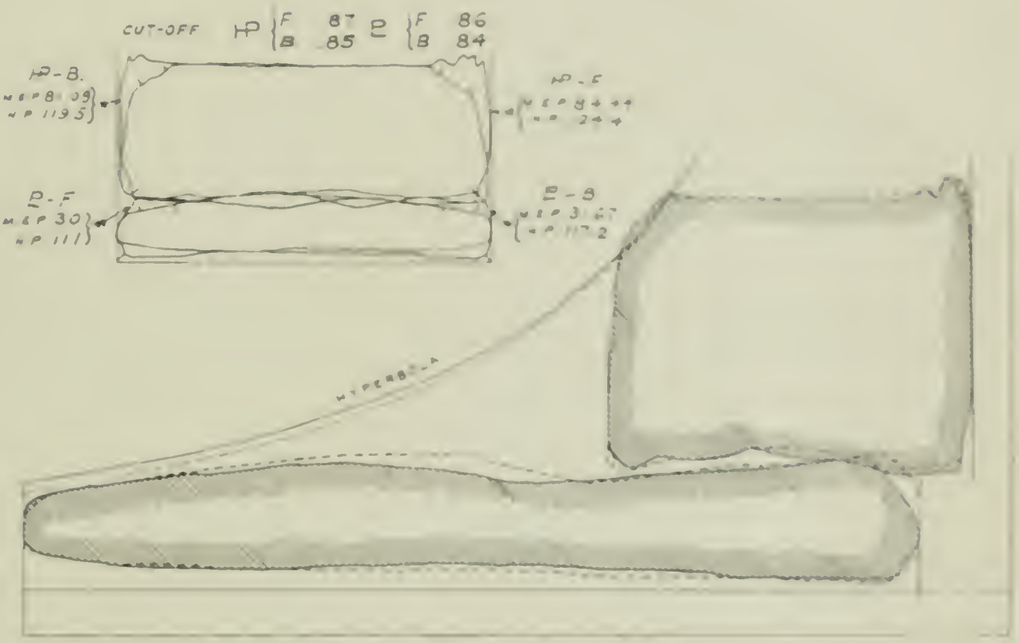
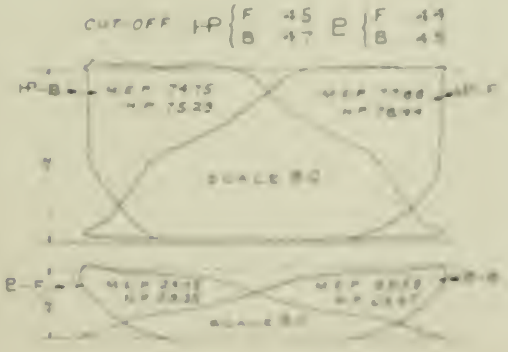


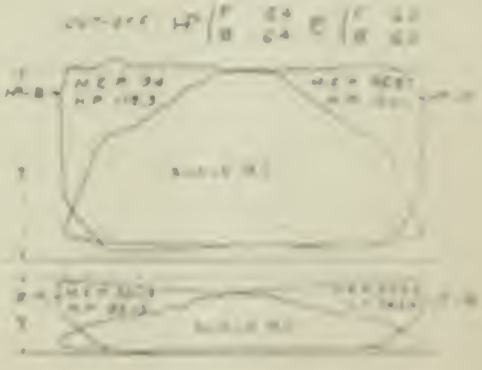
PLATE XXI

U E RR Eng No 58
DIAGRAMS IN SIMPLE SYSTEM
R I Loco Works

No 25 [illegible]
Speed 120 Rev
Steam 128 Notch 7
Av M E P {HP 76 31
E 24 82 Ref to HP 60 81
TOTAL H P 136 08



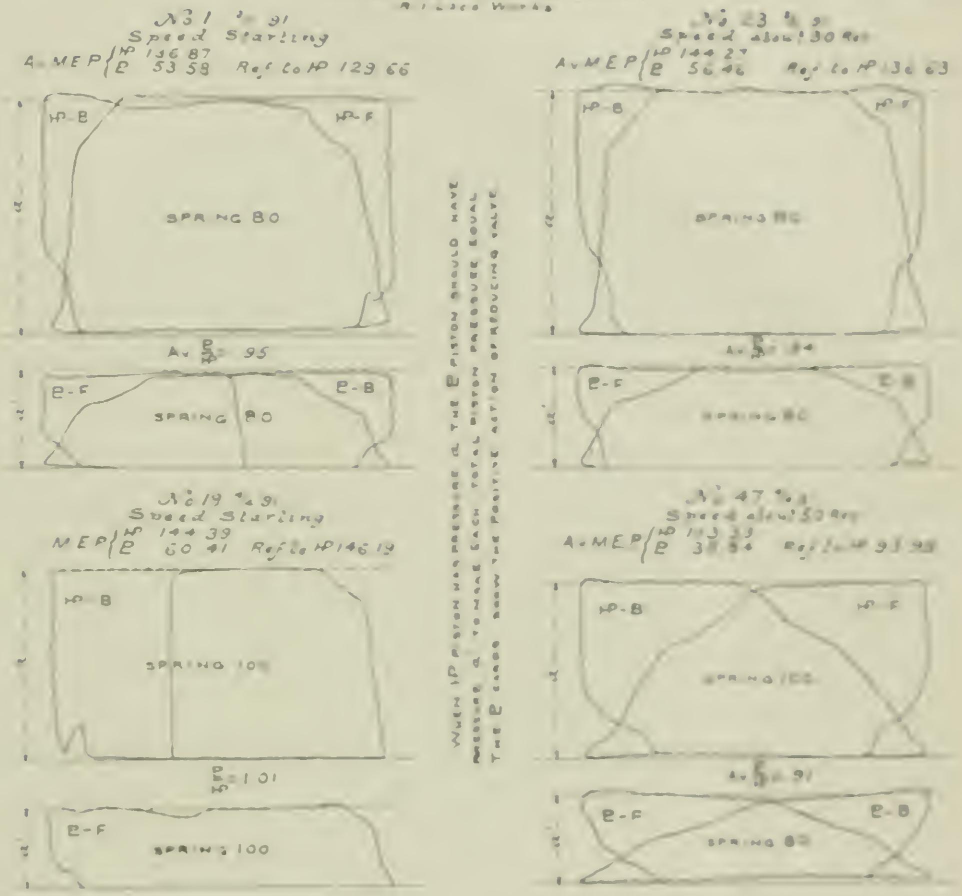
No 42 [illegible]
Speed [illegible] Rev
Steam [illegible] Notch 7
Av M E P {HP 84 [illegible]
E 32 [illegible] Ref to HP [illegible]
TOTAL H P [illegible]



[illegible]
[illegible]

PLATE XXII

ENG No 2600
DIAGRAMS IN SIMPLE SYSTEM
R I Loco Works



U.E.R.R Eng No 58
By
R.I.Loco W'ks ⁸⁄₂₄ 90

Engine starts from rest at x (both cards), both cylinders using direct steam to y (E card), one-half revolution.

a is initial pressure in HP cylinder. a' is initial pressure which E cylinder should have, in order to make total pressures on both pistons equal.

x is the difference between pressure in receiver at time of changing into compound, and normal pressure in receiver when running compound, reverse lever remaining the same.

No 20
Steam 150 Notch 7 Scale 80

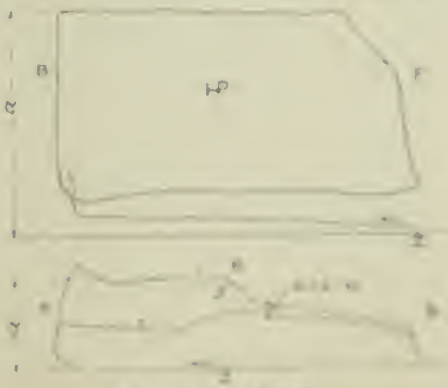


PLATE XXIII

No 19
Steam 148 Notch 7 Scale 80.

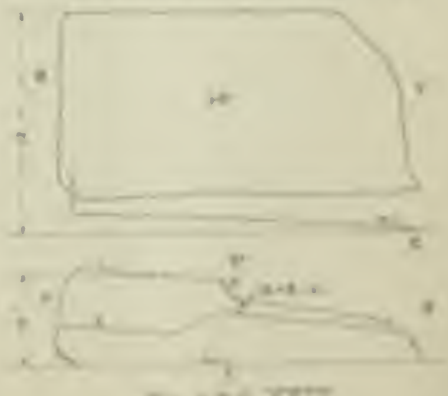


PLATE XXIII

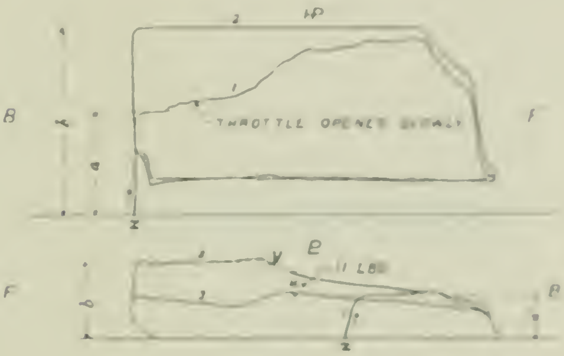
PLATE XXX

No 14.
U.E.R.R. Eng No 58
Steam 125. Notch 7. Scale 80
R.I.Loco.W'ks 2/21 '90

*Engine starts from rest at **z**, (both cards), both cylinders using direct steam to **y**, (LP card), nearly one revolution.*

***a** is first initial pressure in HP cylinder. **a′** is first initial pressure which LP should have, in order to make total pressures on both pistons equal. **b** is third initial pressure in HP cylinder. **b′** (LP card) is a pressure such that the ratio of **b** to **b′** is the same as the ratio of **a** to **a′**.*

***x** is the difference between pressure in receiver at time of changing into compound and normal pressure in receiver when running compound, reverse lever remaining the same.*



U.E.R.R. Eng No 58
By
R.I.Loco.W'ks 2/21 '90

Engine starts from rest at z (both cards), both cylinders using direct steam, and changes into compound during exhaust stroke (LP card), not less than one half revolution.

***a** is initial pressure in HP cylinder. **a′** is initial pressure which LP cylinder should have in order to make total pressures on both pistons equal.*

No 15.
Steam 118 Notch 7 Scale 80

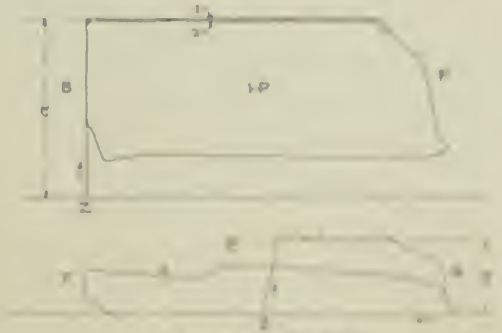


PLATE XXXI

No 18
Steam 145 Notch 7 Scale 80

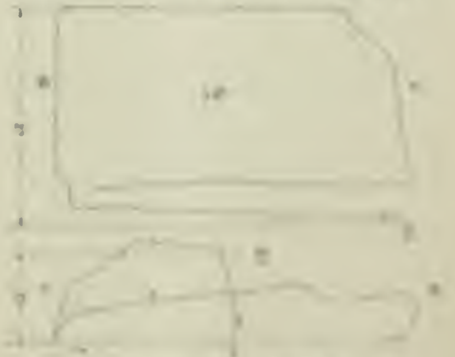
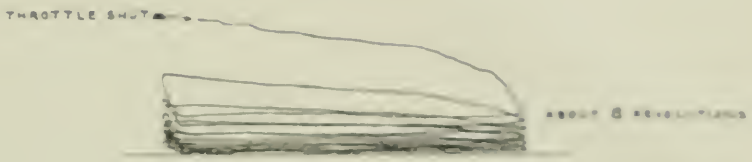
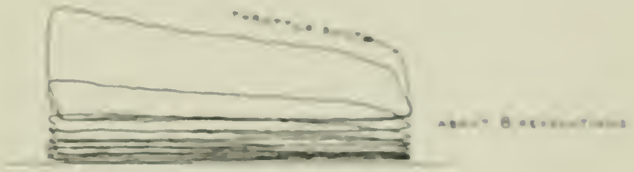


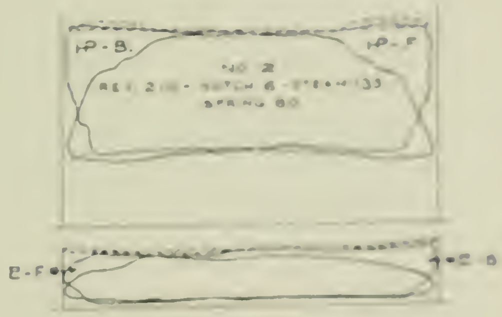
PLATE XXXII

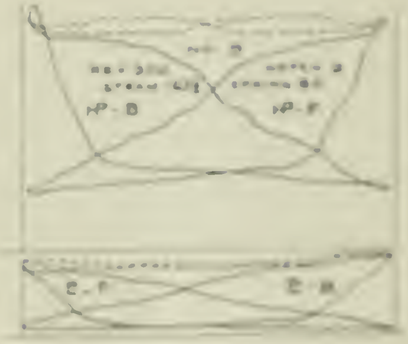
U. E. R.R — ENG. No 58 PLATE XXVIII

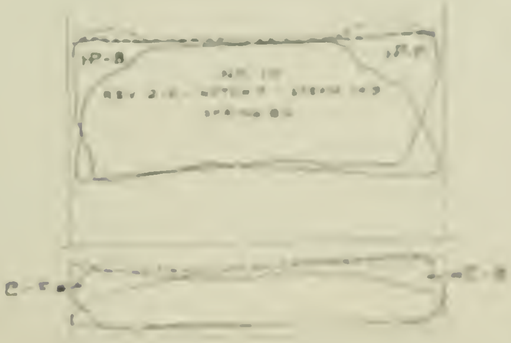


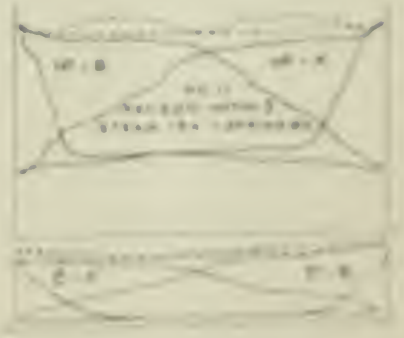


U. E. R.R — ENG. No 58 PLATE XXIX





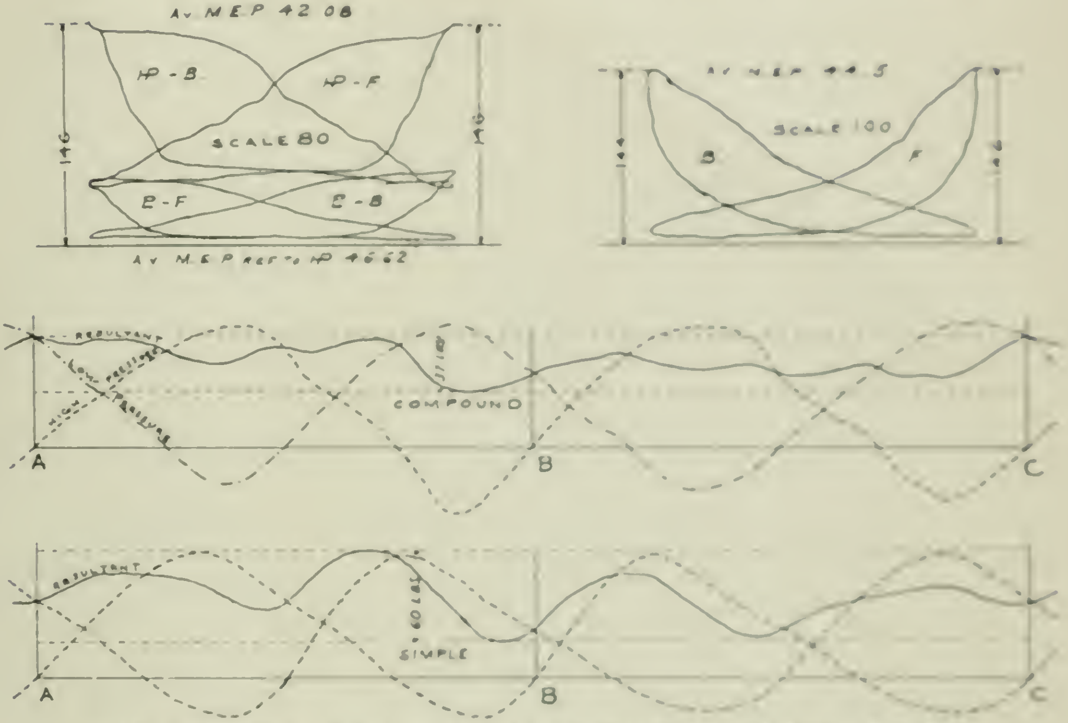




ROTATIVE EFFECTS

PLATE IXX

ON SIMPLE AND COMPOUND ENGINES FROM ACTUAL CARDS
OF SIMILAR INITIAL STEAM PRESSURES AND MEAN EFFECTIVE PRESSURES

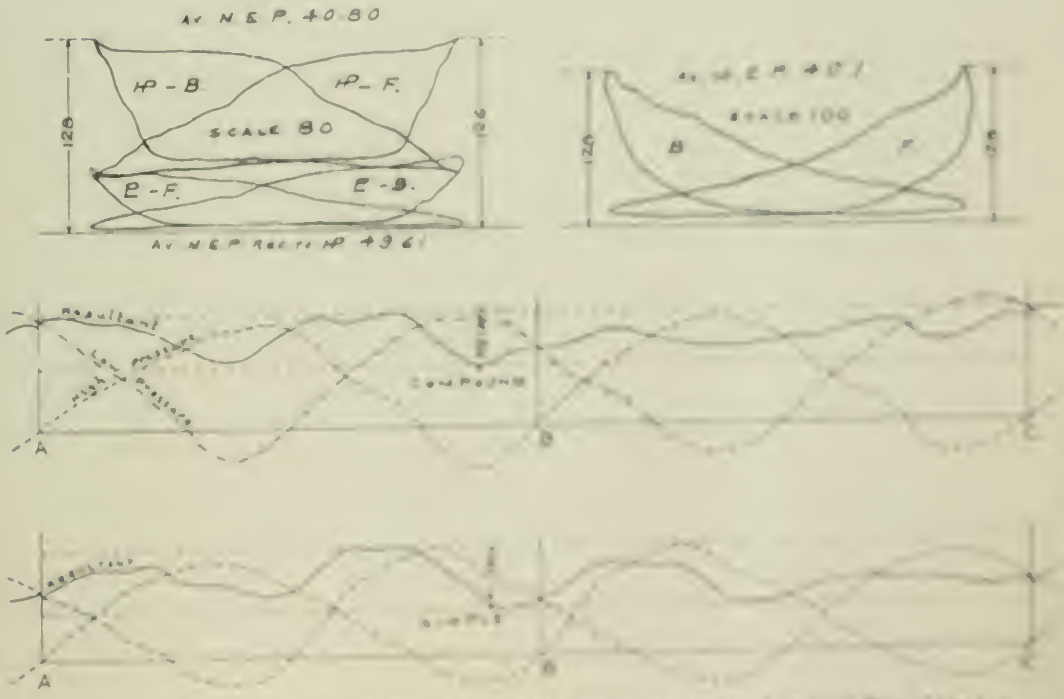


On each Diagram, straight line ABC is the development of Crank Pin Circle, scale, 2"=1ft. A and C are at Back Dead Point of Left crank. B is at Forward Dead Point of Left crank. Heights above ABC represent ROTATIVE EFFECTS, 1" in height equalling 80 lbs per sq. in of HP piston, exerted at Crank Pin at Right Angles to Crank.

ROTATIVE EFFECTS

PLATE XXII

ON SIMPLE AND COMPOUND ENGINES FROM ACTUAL CARDS
OF SIMILAR INITIAL STEAM PRESSURES AND MEAN EFFECTIVE PRESSURES



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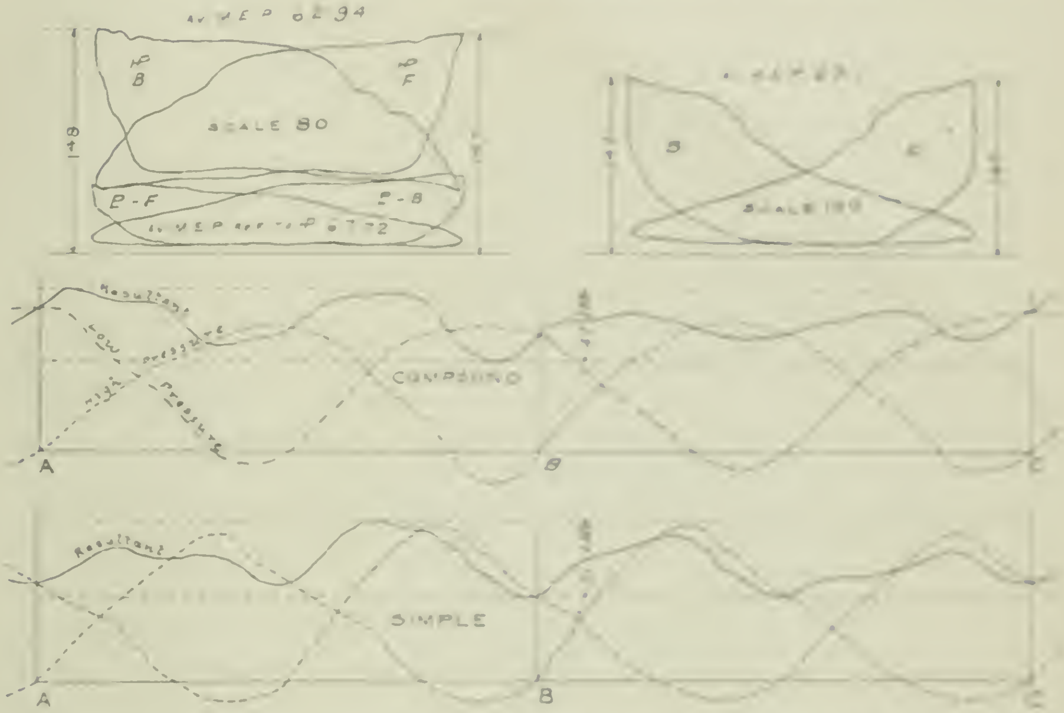
ROTATIVE EFFECTS. PLATE XXXI

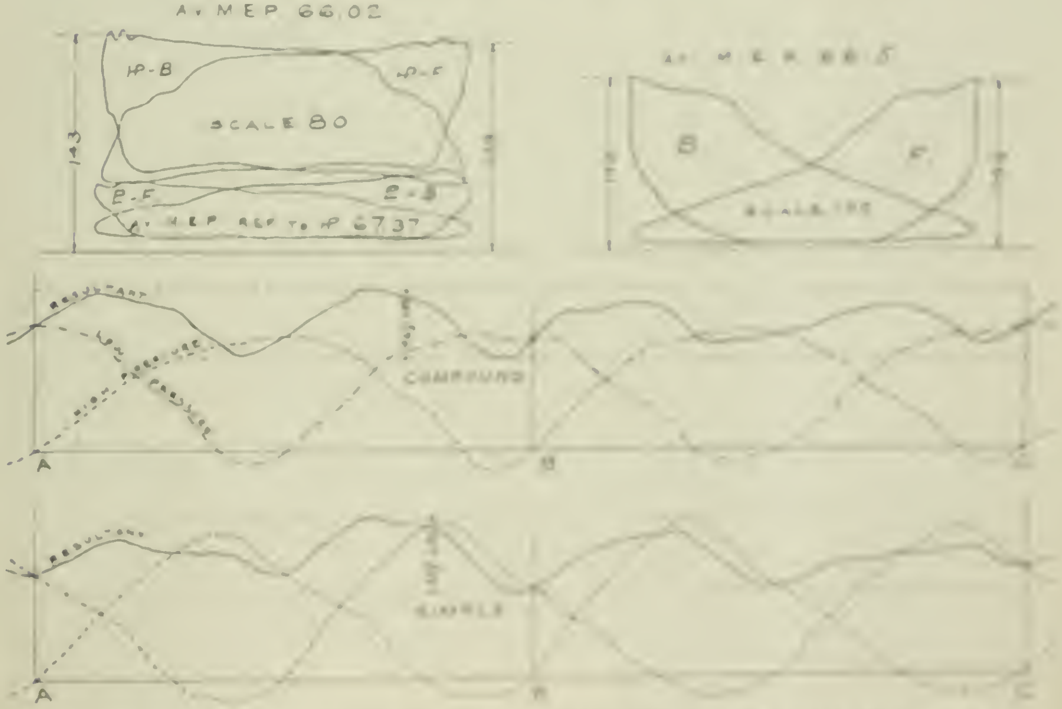
ON SIMPLE AND COMPOUND ENGINES FROM ACTUAL CARDS
OF SIMILAR INITIAL STEAM PRESSURES AND MEAN EFFECTIVE PRESSURES.



On each Diagram, straight line ABC is the development of Crank Pin Circle, scale, 2=1 ft. A and C are at Back Dead Point of Left crank. B is at Forward Dead Point of Left crank. Heights above ABC represent ROTATIVE EFFECTS 1 in height equalling 80 lbs per sq in of HP piston, exerted at Crank Pin at Right Angles to Crank.

ROTATIVE EFFECTS PLATE XXXII

ON SIMPLE AND COMPOUND ENGINES FROM ACTUAL CARDS
OF SIMILAR INITIAL STEAM PRESSURES AND MEAN EFFECTIVE PRESSURES.



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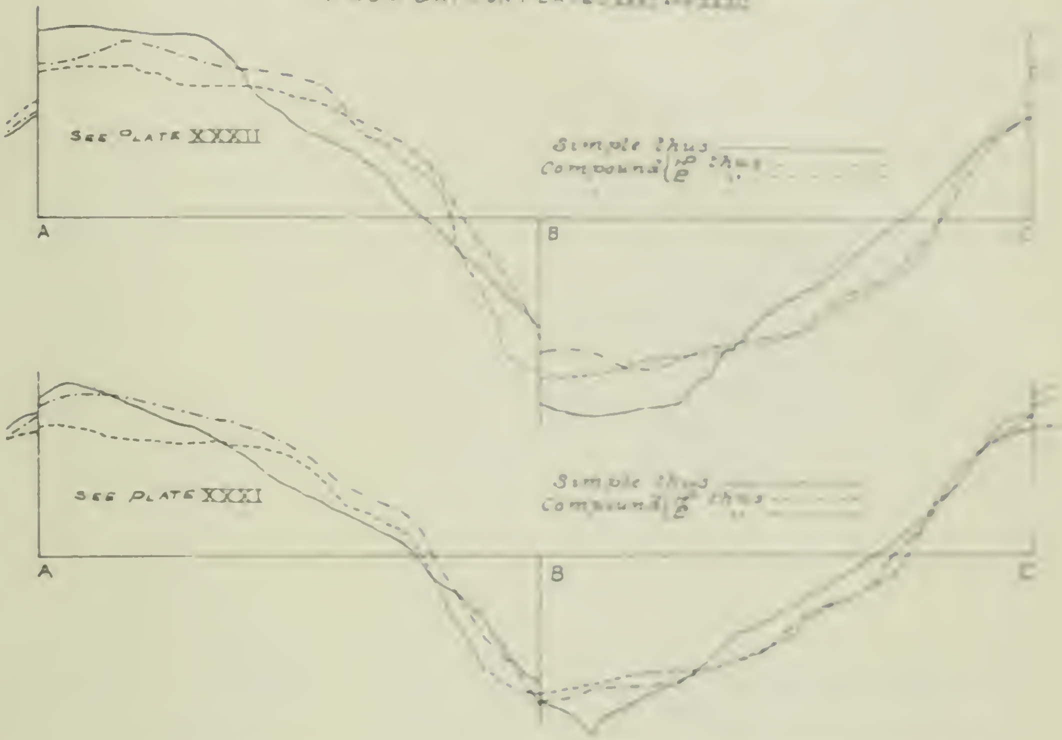
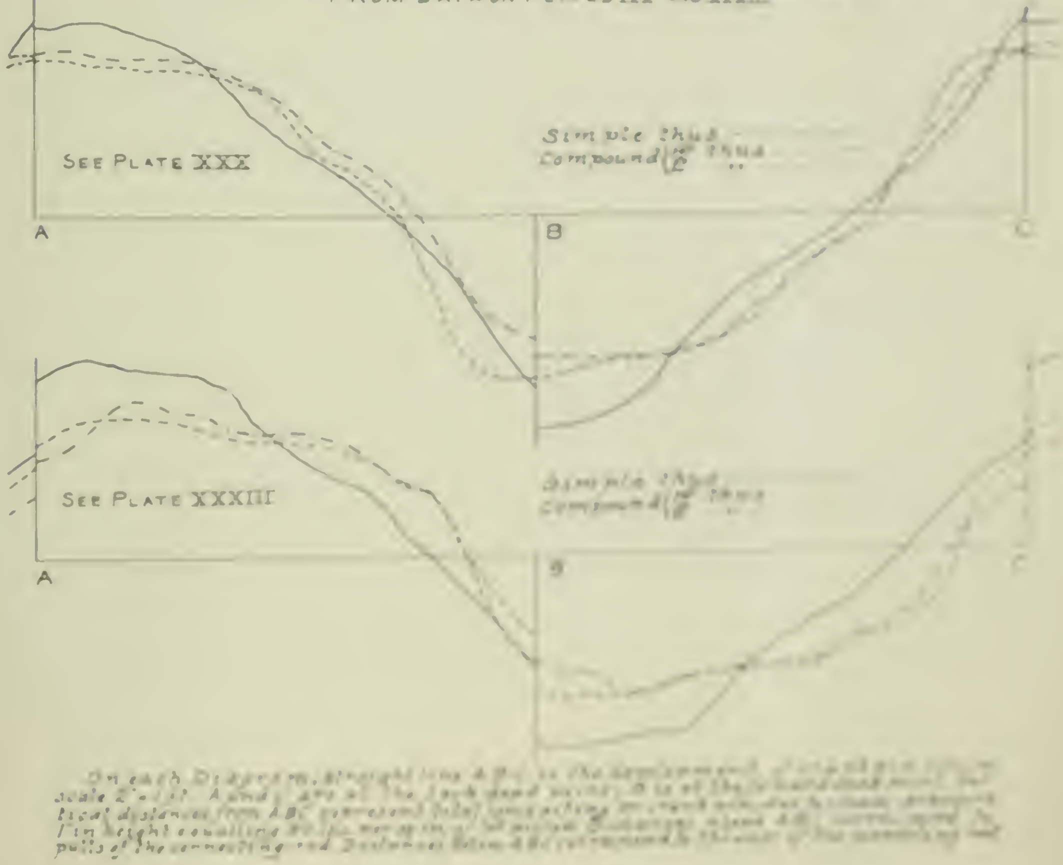
CRANK-PIN STRESS, PLATE XXXIV
ON SIMPLE AND COMPOUND ENGINES
FROM DATA ON PLATES XXXI AND XXXII



On each Diagram, straight line ABC is the development of crank pin circle, scale 2"=1 ft. A and C are at the back dead point; B is at the forward dead point. Vertical distances from ABC represent total force acting on crank-pin, due to steam pressure, 1" in height equalling 80 lbs per sq in of HP piston. Distances above ABC correspond to pulls of the connecting-rod. Distances below ABC correspond to thrusts of the connecting-rod.

CRANK-PIN STRESS PLATE XXXV
ON SIMPLE AND COMPOUND ENGINES
FROM DATA ON PLATES XXX AND XXXIII



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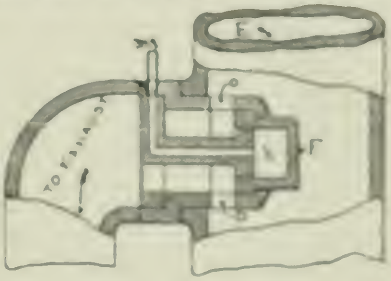
VE WORKS. PATENTED SEPT. 22. 91



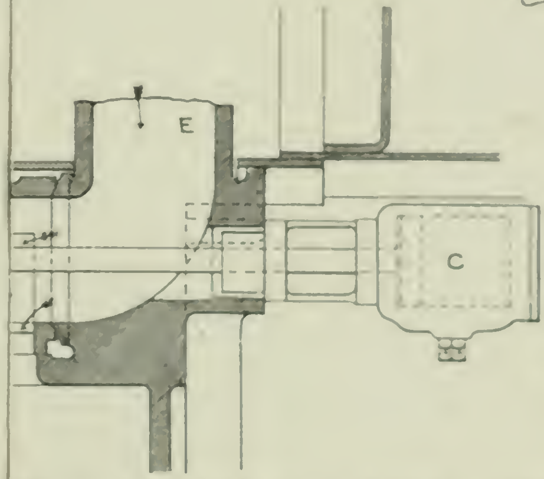
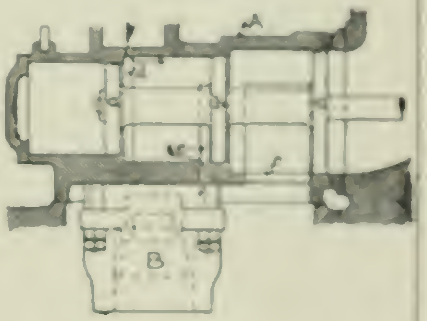


FIG. III.



ORTION OF RECEIVER WITH EXHAUST VALVE

OWS SAME WHILE RUNNING SIMPLE.

TO INTERCEPTING VALVE. – E (IN FIG'S I-II-III) THE RECEIVER – F (IN FIG'S II-III) EXHAUST VALVE

CING VALVE B. f (IN FIG'S II-III) PORT FROM A INTO PASSAGE TO C STEAM CHEST

(IN FIG'S II-III) PORT THROUGH EXHAUST VALVE CASING.

E, ALLOWING THE EXHAUSTS FROM THE HP CYLINDER TO ESCAPE THROUGH THE
MANNER.

ALVE F IS OPERATED AS FOLLOWS:– THE SMALL PIPE m IS FROM A HAND VALVE
TO EITHER STEAM OR ATMOSPHERE. WHEN DESIRING TO RUN COMPOUND,
WITH ATMOSPHERE, THE RECEIVER STEAM KEEPING VALVE F IN
G. II. TO RUN SIMPLE m IS CONNECTED TO STEAM WHICH WILL HOLD THE
III, THE PORTS O OPENING E TO THE EXHAUST. THE VALVE F TAKES
AT ANY TIME AT THE WILL OF THE ENGINEER.

THAT, IN CASE OF BAD CONDITIONS OF STARTING, THE ENGINE
AS A SIMPLE ONE AT THE WILL OF THE ENGINEER BY
AUST VALVE BEFORE STARTING, AND THAT UPON ITS RELEASE THE
L AUTOMATICALLY TAKE THE COMPOUND POSITION OF FIG II,
THE FIRST PARAGRAPH.

DIAGRAM OF INTERCEPTING VALVE — BY R. I. LOCOMOTIVE WORKS.

PATENTED SEPT. 22, 91.

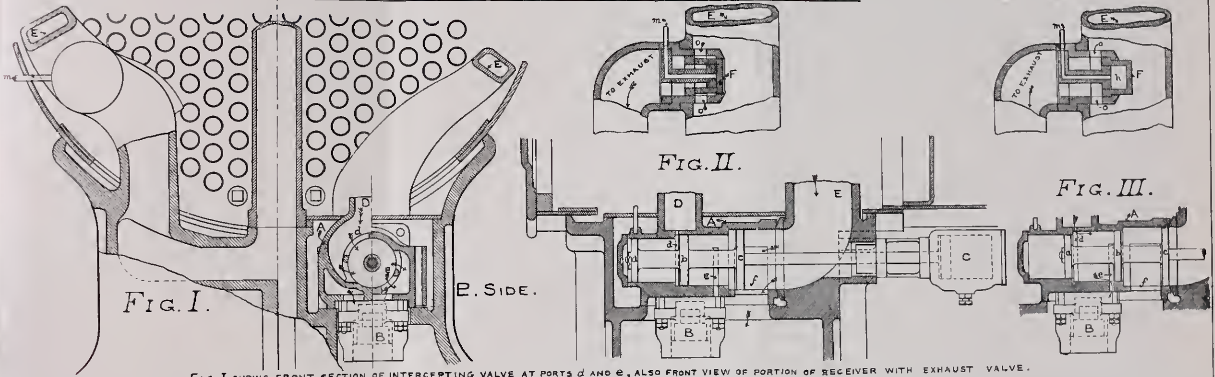


Fig. I shows front section of intercepting valve at ports d and e, also front view of portion of receiver with exhaust valve.

Fig. II shows side section of same while running compound. Fig. III shows same while running simple.

A (in figs I-II-III) intercepting valve casing.— B (in fig's I-II-III) reducing valve.— C (in fig II) oil dash pot.— D (in fig's I-II) pipe from mainsteam pipe to intercepting valve.— E (in fig's I-II-III) the receiver.— F (in fig's II-III) exhaust valve

a-b-c (in fig's II-III) intercepting valve piston. d (in fig's I-II-III) port from D through A. e (in fig's I-II-III) port from A into the reducing valve B. f (in fig's II-III) port from A into passage to LP steam chest.

m (in fig's I-II-III) small pipe and passage connecting hand valve in cab to chamber h. o (in fig's II-III) port through exhaust valve casing.

The device shown above operates as follows:

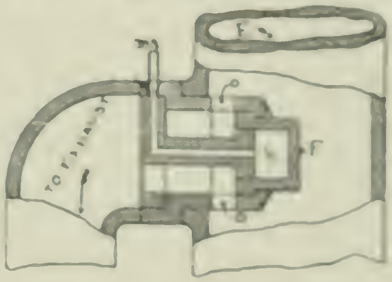
The intercepting valve being in any position as in Fig. II, and the exhaust valve closed as in Fig. II, the throttle being opened; boiler steam will pass to the HP. cylinder in the usual manner, and also through pipe D into the intercepting valve A, causing the piston to move into the position shown in Fig. III. In this position the receiver is closed to the LP. cylinder by the piston c, and steam from D passes through ports d and e, and reducing valve B, into the LP. steam chest; the pressure being reduced from boiler pressure in the ratio of the cylinder areas. The piston a-b-c, is so proportioned that it will automatically change to the compound position shown in Fig. II, when a predetermined pressure in the receiver E has been reached by exhausts from the HP. cylinder. The engine thus starts with steam in both cylinders, and automatically changes to compound at a desired receiver pressure.

The engine may be changed from the compound system to the simple at any time, at the will of the engineer, by opening the valve F connecting the receiver to the exhaust pipe, allowing the exhausts from the HP cylinder to escape through the nozzle in the usual manner.

The exhaust valve F is operated as follows:—the small pipe m is from a hand valve in cab connecting it to either steam or atmosphere. When desiring to run compound, m is in connection with atmosphere, the receiver steam keeping valve F in position as per Fig. II. To run simple m is connected to steam which will hold the valve F as in Fig. III, the ports o opening E to the exhaust. The valve F takes either position at any time at the will of the engineer.

It is obvious that, in case of bad conditions of starting, the engine may be operated as a simple one at the will of the engineer by opening the exhaust valve before starting, and that upon its closure the piston a-b-c will automatically take the compound position of Fig. II, as described in the first paragraph.

VE WORKS. PATENTED SEPT. 22. 91.



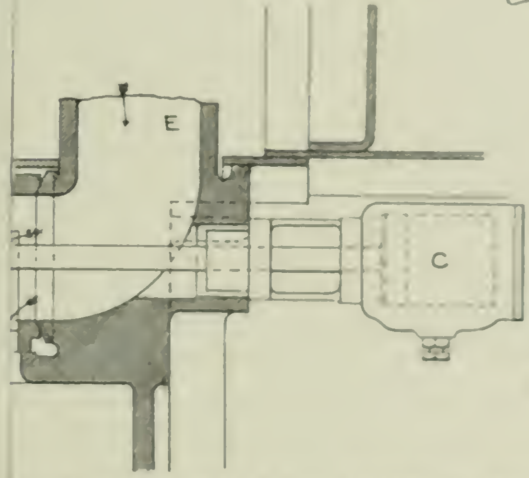


FIG. III.

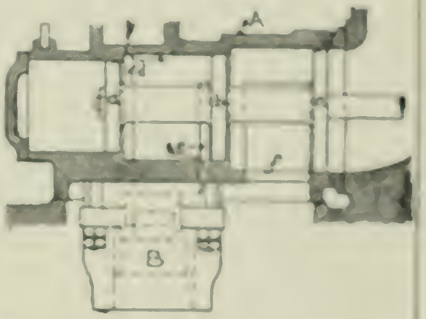


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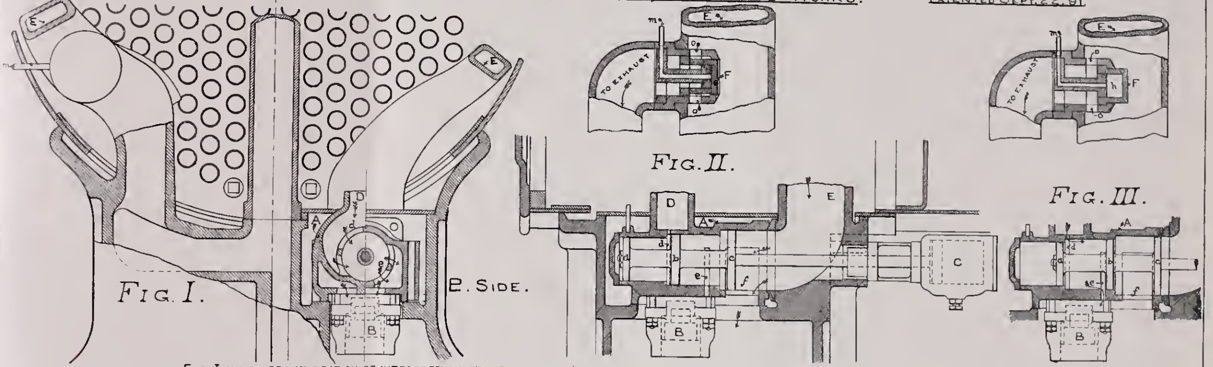
Diagram of Intercepting Valve — by R. I. Locomotive Works.

Patented Sept. 22. 91



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A (in fig's I-II-III) intercepting valve casing. — B (in fig's I-II-III) reducing valve. — C (in fig II) oil dash pot. — D (in fig's I-II) pipe from main steam pipe to intercepting valve. — E (in fig's I-II-III) the receiver. — F (in fig's II-III) exhaust valve

a-b-c (in fig's II-III) intercepting valve piston. *d* (in fig's I-II-III) port from D through A. *e* (in fig's I-II-III) port from A into the reducing valve B. *f* (in fig's II-III) port from A into passage to L.P. steam chest.

m (in fig's I-II-III) small pipe and passage connecting hand valve in cab to chamber *h*. o (in fig's II-III) port through exhaust valve casing.

The device shown above operates as follows:

The intercepting valve being in any position as in fig. II, and the exhaust valve closed as in fig. II, the throttle being opened; boiler steam will pass to the H.P. cylinder in the usual manner, and also through pipe D into the intercepting valve A, causing the piston to move into the position shown in fig III. In this position the receiver is closed to the L.P. cylinder by the piston c, and steam from D passes through ports *d* and *e*, and reducing valve B, into the L.P. steam chest; the pressure being reduced from boiler pressure in the ratio of the cylinder areas. The piston a-b-c, is so proportioned that it will automatically change to the compound position shown in fig. II, when a predetermined pressure in the receiver E has been reached by exhausts from the H.P. cylinder. The engine thus starts with steam in both cylinders, and automatically changes to compound at a desired receiver pressure.

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